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HUMAN ANATOMY

GENERAL AND DESCRIPTIVE

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HUMAN ANATOMY

GENERAL AND DESCRIPTIVE

FOR THE USE OF STUDENTS

BY

JOHN CLELAND, M.D., LL.D., D.Sc., F.R.S.
PROFESSOR OF ANATOMY IN THE UNIVERSITY OF GLASGOW

AND

JOHN YULE MACKAY, M.D., C.M.
PROFESSOR OF ANATOMY IN UNIVERSITY COLLEGE, DUNDEE; LATE SENIOR DEMONSTRATOR IN THE UNIVERSITY OF GLASGOW

WITH 630 ILLUSTRATIONS, OF WHICH 257 BY THE AUTHORS ARE NOW PRINTED FOR THE FIRST TIME

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PREFACE.

In this work it is sought to provide for students of Medicine and of Science a complete compendium of the Anatomy of the Human Body, which shall, both in macroscopic and microscopic detail, give a clear and full account of universally received facts, while incorporating the results of recent research and indicating the relations of structure to function. Development has been gone into, although with brevity, yet with the object kept constantly in view of enabling the student to understand the morphological import of the adult architecture. But there is much morphological speculation which would be out of place in a volume like this, not professing to treat of the anatomy of any animal form other than the human body.

As respects topographical relations and other matters of professional interest, it has been the aim of the authors to supply the wants of both physicians and surgeons.

When it has seemed expedient, reference has been made to the names of authors and even to individual memoirs, but it has been left to larger treatises to furnish the investigator with lists of titles of books and recent contributions to anatomical literature.

The sections devoted to the Muscles, the Heart and Bloodvessels, the Lymphatics, and also the Distributed Nerves, are the independent work of Dr. Mackay, who has also selected the illustrations for them, and supplied some from his own pencil. The rest of the book is written by Dr. Cleland, who is also responsible for the general arrangement.

To more than half of the illustrations no name is attached; and these (with the exception of a few which have already appeared in Dr. Cleland's *Animal Physiology* in Messrs. Collins' Advanced Scientific Series) have been specially prepared for the present work. Photography has been largely made use of in the section on the

Skeleton, and it is hoped that by this means superior accuracy has been gained, while distinctness has been secured by the aid of touching, often of an elaborate kind, which had to be taken in hand by Dr. Cleland himself. He has likewise provided the original sketches of all illustrations whose authorship is not specially indicated. The source of every illustration which has been borrowed is acknowledged.

In some instances photographs taken directly from microscopic objects have been secured owing to the kindness and skill of the distinguished oculist, Dr. Thomas Reid, and some of those representing structures connected with the eye have been taken from Dr. Reid's own preparations.

In the preparation of the letterpress, valuable assistance has been obtained from the works of many writers, among which there are specially to be mentioned in Microscopy those of v. Kölliker and Toldt, in Embryology those of His and Hertwig, in the Central Nervous System the *Nouvelles Idées sur le Système Nerveux* of Ramón y Cajal, in Surgical Anatomy the work of Treves, and, in many parts, Quain's *Anatomy*, particularly the tenth edition.

The University,
Glasgow, *September*, 1896.

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CONTENTS.

THE MUSCLES AND FASCIAE.

LIST OF ILLUSTRATIONS.

INTRODUCTION.

Anatomy and Dissection are two words etymologically equivalent, one from the Greek and the other from the Latin. But while the word Dissection retains its primitive meaning, namely, the cutting of parts asunder, the word Anatomy is applied to the conditions of structure which Dissection brings into view, and, widening its signification still further, has become the designation of the science which investigates the structure of organisms.

All Anatomy is resolvable into two parts: first, the observation and record of structures, and secondly, the consideration of their meaning. One mode of considering structure is with reference to function, namely, its utility in the organism of which it is a part, and the arrangements for its own growth: this is *Physiological Anatomy*. Another mode is with reference to form alone, either in its relation to structures in the same animal and in others, or in relation to the series of phases through which it has passed in its development, and this is properly termed *Morphological Anatomy*. But physiological and morphological anatomy are not unconnected, for structures which appear in one animal or in one stage of growth are modified in others in conformity with functional requirements.

The connection of physiological and morphological anatomy is well illustrated in the study of development, which as a process of growth belongs to the domain of physiology, but as a series of successive forms of structure is one of the foundations of morphological anatomy.

The forms of animals are widely diverse, and are classified in groups according to the greater or less degree of their structural resemblance; and the same parts can be traced with modifications in animals more or less remote one from another, or in the two sexes of one species. So also, in the same animal, structures similar one to another may occur placed symmetrically like the limbs, or repeated in longitudinal series like the ribs. Structures corresponding in any of these ways are said to be homologous, and their relationship is called *Homology*, while an animal which has its structures arranged in a chain of homologous parts is said to be segmented, and the parts of the chain are called *segments*, *somatomes*, or *metameres*.

Human anatomy is the study of the structure of the human body, and inasmuch as organisms are vegetable and animal, and the human body is the highest animal organism, human anatomy has to deal not only with shapes special to man, but also with structures found in modified form in other animals, and even with elements of texture common to animals and vegetables. Human anatomy is therefore only a branch of a larger science. The anthropotomist is incompetent, unaided by comparative anatomy, to deal with many questions of morphology of human structures, and he must extend his researches into physiology to comprehend their functional significance.

Human anatomy is important, not only in its relations to science, but in the assistance which its facts afford to other pursuits. Thus, artistic anatomy, the study of the human frame in relation to its correct delineation by sculptors and painters, is a branch which admits of much greater attention than it has yet received; it does not, however, come within the scope of the present work. More closely bearing on our purposes is the assistance which human anatomy renders to medicine and surgery, lying as it does at the foundation of the precision with which anatomical details are taught in our medical schools; and, indeed, it is to be noted that many details respecting the precise relations of parts, which do not appear to have great scientific interest, are most important in surgery.

The human body presents for consideration textures, and organs composed of textures. The investigation of the textures is called *Histology*, and includes all microscopic anatomy whether of diffused structures or of special organs, while the term *General Anatomy* excludes the microscopy of special organs and embraces the whole consideration of parts distributed through different regions of the body.

The special organs form the subject of *Descriptive Anatomy*. They may be arranged in systems, such as the osseous, muscular, vascular, nervous and visceral; and when these are taken in series, as will be done in this work, the method of instruction is called *Systematic Anatomy*. But the different parts may also be brought under notice in the order in which they are laid bare in dissection of the different regions; and this is called *Regional* or *Topographical Anatomy.*

Methods. In a text book of this sort, methods do not fall to be considered in detail; but some of them may be enumerated. The most important method of Anatomy is *Dissection*, from which the science takes its name; and to facilitate dissection, as well as to render preparations permanent, preservative substances require to be used. *Maceration* is employed for the clearing of bones from their surroundings, and sometimes for the separation and exhibition of other structures. *Injection* is used to dilate the larger bloodvessels and fill them with solid material, and also to display microscopic tubes by filling them with coloured fluid. Continuous *Sections* are used both in microscopic and larger anatomy; and in microscopic anatomy *staining* with dyes is largely resorted to.

Experiment on animals has a certain value as an auxiliary in advancing the anatomical knowledge of the nervous centres, but while its physiological results are all-important, the purely anatomical deductions drawn from the pursuit of this method are necessarily open to question.

Descriptive terms. In describing the forms and relative positions of structures there are certain terms required which, however simple in themselves, have yet a certain conventional use to which it may be convenient to direct the student's attention at the outset. The words *anterior, posterior, superior* and *inferior* are used in human anatomy in reference to the body in the erect posture. This is rather unfortunate, seeing that the same words applied to the lower animals are used in reference to their ordinary positions, and become quite ambiguous in descriptions which refer indifferently to both the lower animals and man, such as occur in embryology as well as comparative anatomy. In such circumstances it is advisable to avoid the words in question altogether. The words *dorsal* and *ventral* can always be used to express the directions which are in the human subject anterior and posterior, and while no convenient words have hitherto been found as substitutes for what in human anatomy is expressed by superior and inferior, *proserial* and *retroserial* may be suggested as self-explaining terms completely fitted to supply the want. The *mesial plane* is that in which the right and left half of the body meet; and any line which lies in that plane is the *middle line* of the surface spoken of. The words *external* and *internal* are held to refer technically to greater or less distance from the mesial plane, while the words *deep, subjacent,* and *superficial* express greater or less distance from the surface. But *external* and *internal* were often used to signify *superficial* and *deep* before the modern convention had been arrived at, and relics of former usage survive in the particular names given to certain structures, as, for example, the expressions *external* and *internal abdominal rings,* which would be much better spoken of as *superficial* and *deep rings,* particularly as it happens that the ring called external is in a position nearer the middle line than that known as the internal. The word *sagittal,* introduced by some German writers instead of dorso-ventral, and the word *frontal* or *coronal,* to express a transverse longitudinal plane, have come much into use. Generally, it may be laid down that no terms should be used which admit of ambiguity.

With regard to the naming of individual structures, it may be noted that more than one attempt has been made to impose uniformity of nomenclature by the arbitrary authority of an individual or a committee. It may be doubted if any such attempt can possibly be successful.[1] But,

[1] A supplemental volume of the *Archiv für Anatomie und Entwickelungsgeschichte,* 1895, is devoted to "Nomina Anatomica, Verzeichniss der von der anatomischen Gesellschaft auf ihrer IX. Versammlung in Basel angenommenen Namen. Eingeleitet und im Einverständniss mit dem Redactionsausschuss erläutert von Wilhelm His." This work is most important for consultation; but the adoption of its recommendations in this country would, in a large number of instances, involve the abandonment of good names in general use for others whose advantages are not obvious.

manifestly, certain general principles ought to be observed. Names in common use ought not to be lightly set aside. When new names have to be introduced, they ought to be short, euphonious, and etymologically accurate, and ought, as far as possible, to explain themselves; and newly discovered structures should be referred to by a descriptive name, whether the name of the discoverer be added or not. Names ought always to be used in exact accordance with the definition given by the introducer, otherwise the same word comes to have two meanings, and its precision is lost. Generally, terms are to be preferred which cannot possibly be misunderstood, and when a term has unfortunately come to be used with different limits from those of its original meaning, it may be well to mention the name of the author responsible for the definition followed.

GENERAL ANATOMY.

THE LIVING CORPUSCLE.

In the simplest living beings, whether animal or vegetable, the functions of life are carried on by a single *corpuscle*, a mass of pulp of microscopic dimensions, scarcely begun to be differentiated into parts for different offices. One of the earliest complications of such a mass is the distinction of a firmer rounded body, the *nucleus*, within it; and in certain instances, notably those of vegetable type, there is added an envelope or *cell-wall* round about. Such corpuscles are not only the simplest form of adult organisms, but furnish the embryonic origin of all others; and are the most obvious living elements of the adult texture. They are, in fact, units of life. They arise, probably in every instance, from pre-existing corpuscles; and thus the living corpuscles of the textures are comparable with separate organisms in possessing parentage, as well as in other respects.

They are very commonly called **nucleated cells**. But the term 'cell' had its origin in the importance once attributed to a structure which is now known to be really no part of the living corpuscle, the cell-walls formed of cellulose in plants being familiar to botanists before their contents were well appreciated. Robert Brown first observed and named the nucleus, while another botanist, v. Mohl, observed that there was within the cell a special delicate substance which he called *protoplasm*. Schwann (1839) was the first to realize that organization proceeded by essentially the same methods in animals as in plants, and naturally adopted the word 'cell' from the botanists, though aware that a cell-wall was not in every instance present. It was not till much more recent years that histologists generally became aware that the protoplasm and nucleus are, as is now conceded, the most important elements of living corpuscles in both animals and vegetables, and that the cell-wall when present is adventitious.

Protoplasm is simply a convenient term for the substance surrounding the nucleus and constituting the mass of the living corpuscle. Its meaning cannot with propriety be extended so as to include the substance of the more specialized living elements, such as muscular fibre, which, although nearly allied in chemical composition, have peculiarities of their own.

It probably, however, always possesses some amount of the contractility which is more highly developed in muscle. This property of contractility is exhibited very evidently in unwalled corpuscles found in the blood and in the connective tissues, and in them takes the form of a power to throw out processes and generally to change their shape in every direction, like the minute animals called Amoebae; hence such corpuscles are called amoeboid or wandering. It is as yet impossible to say if protoplasm has for its basis a single definite chemical substance, or what its precise composition is in the living state, but it is of highly complex nitrogenous constitution, coagulable with heat, soluble in alkalies, belongs, so far as can be ascertained, to the albuminoid group, and is easily subjected to staining. It may present an almost uniform appearance, or may be distinctly granular. This granular appearance may be due to molecules of oil, lecithin, or other substance; and the analogy of muscular contraction would suggest that there is always some other substance besides the main chemical constituent present necessary for the exhibition of contractility. Even, however, apart from granules and fluids which may be mixed with it, protoplasm is now held by investigators who have given special attention to the subject to be resolvable into a network or *spongioplasm,* and an amorphous material or *hyaloplasm* in the meshes.

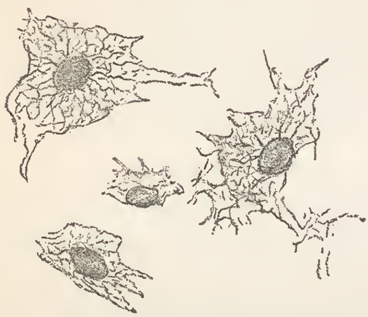


Fig. 1.—Nucleated Corpuscles from the tissue investing the amnion of an embryo lamb. The threads of spongioplasm are made evident by staining.

Nuclei are firmer bodies, spherical, flattened or elongated, with a regular outline so definite that it must be regarded as a membrane. They often occur without apparent protoplasm around them. They are more susceptible of staining than is protoplasm, and have been found to exhibit at times a close network of threads within them, of specially stainable character, and embedded in unstainable substance. Nuclei often contain one or more highly refractive bodies in their interior, *nucleoli,* which may stain more deeply still.

Multiplication of nucleated corpuscles. Nuclei have been long known to play an important part in the multiplication of corpuscles. It was seen that a nucleus became divided into two nuclei before the surrounding protoplasm divided, and that this occurred both in cells surrounded with cell-walls and in corpuscles not so surrounded; and the whole process was termed *fissiparous division,* to distinguish it from budding or the separation of a small portion of the protoplasm (*gemmiparous division*). It is now known that very complicated changes take place in nuclei prior to their dividing, and these processes constitute what is called *karyokinesis* or *mitosis.* They occur very generally; and it is supposed that direct division

without their intervention is quite exceptional; but they have been most fully observed in certain instances, as in plants and in the cartilage and epithelial cells of amphibians.

The following appear to be the most important stages described: (1) The netted appearance of the nucleus is changed to that of coiled

FIG. 2.—CELLS WITH KARYOKINETIC CHROMATIN FIGURES, epithelial cells from gills of larva of salamander. *a*, Nucleus at rest; *b*, a thread formed; *c*, a dense ball; *d*, looser ball or rosette; *e*, monaster; *f*, *g*, *h*, *i*, dyaster and its changes; *k*, two independent nuclei and hour-glass contraction of the whole cell. (Toldt.)

and contorted threads of stainable substance or *chromatin*, while nucleoli and nuclear wall disappear. (2) The coiled threads arrange themselves into a rosette round a centre. (3) The rosette is converted into an equatorial star or *monaster* of threads arranged in loops with their free

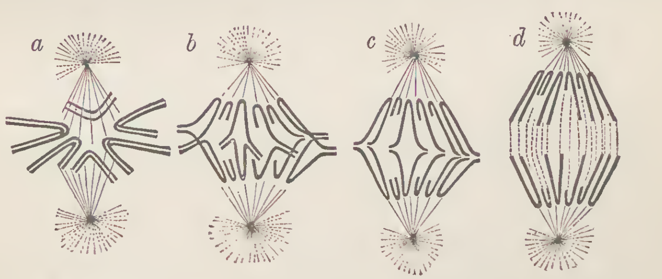


FIG. 3.—MONASTER AND DYASTER WITH ACHROMATIN SPINDLE AND POLAR RAYS. Schema. (Toldt after C. Rabl.)

ends at the circumference, while two radiating arrangements of unstainable material, or *achromatin*, at the poles are united by a *spindle* of delicate lines passing through the centre. (4) Each loop of the monaster splits longitudinally in its whole length, and each daughter-loop, so formed,

parts from its sister-loop in such a manner that the central or curved portions travel to opposite poles, and form a double starry figure or *dyaster*. (5) The protoplasm is divided into two masses, one round each new star, while the stars give place to the appearance of nuclei at rest.[1]

The **cell-wall** is a structure which in certain instances is formed round the nucleated corpuscles. It is seen, for example, distinctly round the columnar epithelial cells of the intestine. Many corpuscles used to be supposed to have cell-walls round them, which are now definitely known to have none. In the case of the adipose vesicle, the wall is formed out of the protoplasm by alteration of its substance; but in most instances there is not sufficient evidence that it is formed in that way, and not by deposit thrown out, like other matrix in which corpuscles lie. It may be questioned if, in their young condition, the corpuscles of animals have ever any cell-wall round them.

Nucleated corpuscles in the textures may be

(1) Massed together with little apparent cement, as in epithelia and embryonic textures.

(2) Embedded in a matrix, as in connective tissue, cartilage and bone.

(3) Elongated into fibres, each derived from (*a*) one corpuscle, as in smooth muscular fibre, or (*b*) a row of corpuscles as in striped muscular fibre, and perhaps, or even probably, in nerve.

Nucleated corpuscles are also found floating free, as in blood and lymph.

THE BLOOD.

Blood consists of two parts, the *plasma* or *liquor sanguinis*, and the blood-corpuscles. The plasma is broadly divisible into serum and fibrin, and the corpuscles into red corpuscles and white. A rough analysis showing those constituents may be made by collecting blood from a wound into an ice-cold vessel. The cold prevents coagulation taking place; the red corpuscles gravitate to the lower part of the vessel, and the plasma is left clear and straw-coloured above, while on further standing a slight milkiness may be noticed near the surface, caused by the white corpuscles rising to the top. On raising the temperature, the plasma forms a transparent coagulum, and the coagulated fibrin gradually contracts so as to separate from the edges of the glass and present a concave surface, while, in the concavity and round about, the serum expelled from the contracting mass is collected. A similar sequence of events takes place, without the precaution of chilling, in various conditions of human blood, as well as normally in the blood of the horse. Practitioners, in the days when

[1] For the literature of mitosis and of histology generally the student may be referred to the sixth edition of Kölliker's *Handbuch der Gewebelehre des Menschen*, and to the tenth edition of Quain's *Elements of Anatomy*.

bleeding was generally practised, termed the straw-coloured layer *buffing,* the contraction of the clot *cupping,* and attached importance in fevers and inflammatory complaints to the blood being buffed and cupped. If blood be agitated with a bundle of twigs while it is being removed from the body, the fibrin at once adheres in a firm contracted coagulum to the twigs, while, in the defibrinated blood which remains, the red corpuscles rapidly separate from the serum.

The red corpuscles or discs, in their characteristic condition, as seen, for example, in blood from a puncture of the finger, are biconcave circular discs, the vast majority of them having exactly one size in any one specimen. Their diameter is variously estimated at from $\frac{1}{3200}$th to $\frac{1}{3000}$th inch. None of them exceed that size, but a few much smaller are often seen in the blood of persons in perfect health. Their colour under the microscope is a uniform orange, corresponding in tint to that of a thin streak of blood on a white plate. But in dark venous blood this is

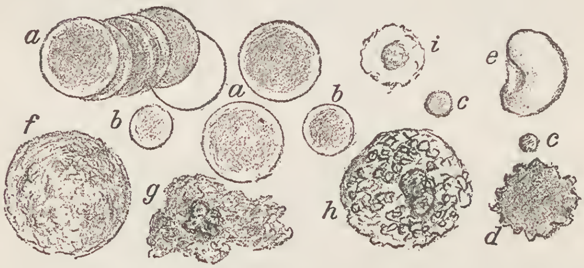


FIG. 4.—BLOOD-CORPUSCLES OF MAN. *a, a,* Red corpuscles of ordinary appearances; *b, b,* occasional red corpuscles of smaller size; *c, c,* minute particles of red substance; *d,* red corpuscle crenated by evaporation; *e,* red corpuscle swollen by addition of water; *f,* finely granular white corpuscle; *g,* similar white corpuscle spread amoeboidly on the glass; *h,* coarsely granular white corpuscle; *i,* small hyaline white corpuscle.

changed to a dull or purplish crimson, and the form is slightly biconvex. Frequently one sees red corpuscles perfectly flat, like a wafer, and without any simulation of a bounding membrane. When they are biconcave and the edges are completely in focus the central part has a darker shade, not unlike a nucleus, but disappearing as the focus is altered. It is only very exceptionally that a nucleus is really met with in a red corpuscle in a grown mammal. But in the young embryo all the red corpuscles are nucleated, and they are larger than those of the adult. On the addition of water, the red substance of the corpuscles becomes diffused through the fluid, while an amorphous solid remainder is left; and if this experiment be performed with defibrinated blood in a test-tube, the solid substance will collect in the form of a white sediment at the bottom. The soluble red substance consists mainly of *haemoglobin,* the insoluble residuum is called the *stroma.*

Haemoglobin is a chemical substance which so far as can be yet ascertained would appear to be decidedly more complex than even albumin.

It takes oxygen freely into its composition when exposed to it, and easily parts with it again. The oxygenated haemoglobin is distinguished as *oxy-haemoglobin*, because the bands which it shows with the spectroscope are different from those of reduced haemoglobin. In the circulation the haemoglobin, at the same time that the oxygen is expelled from its chemical constitution, absorbs carbonic acid, holding it in solution without chemically uniting with it. To these properties of haemoglobin the red corpuscles owe their utility, and there can be little doubt that this substance exists separately in their composition. Yet the haemoglobin and stroma are undoubtedly indistinguishably united in the corpuscles as a homogeneous mass; and the extreme ease with which the corpuscles become elongated in passing through narrow channels, to recover their shape on emerging, precludes the idea that they have a separate cell-wall. Moreover, if blood drawn from the finger be heated, short of coagulation, for a moment over a flame, the red corpuscles will divide in their whole substance in such a manner that, by repeating the experiment, the same specimen may be made to show successively a large number of red corpuscles of half, or less than half, the standard diameter and numbers of small red granules, or all the discs more or less completely broken up into smaller discs or granules, evidently all of the same composition. The blood of the guinea-pig treated in the same way gives off worm-like threads; but if it be first subjected to freezing, the whole corpuscular structure runs into tetrahedral crystals. So also in the rat and squirrel, the whole corpuscular substance may be made to crystallize into hexagonal plates. These have been described as haemoglobin crystals; and crystals both of haemoglobin and of other kinds, in which the substance of the blood is more or less altered, are to be obtained with greater or less ease from the blood of different animals. But it is to be noted that in many instances, including the blood of man, the crystals do not consist of the whole substance of the red corpuscles.

The white corpuscles or leucocytes of the blood are rounded bodies approaching the spherical form, and are much more irregular in size than the red corpuscles. The majority are a little larger than the red corpuscles, but some of them are smaller, while others are exceptionally large. The average size may be stated at from $\frac{1}{2500}$th to $\frac{1}{3000}$th of an inch, or even less. They have a more or less turbid appearance, but are cleared by the addition of water or acetic acid, and then there come distinctly into view one or more nuclei, or a multipartite nucleus, in their interior. Even outside the body they can, if proper precautions are taken, be observed to be capable of great change of shape of an amoeboid kind, flattening and sending out branches or pseudopods, and changing their position. So also in the web of the frog's foot, or in the undetached mesentery of a rabbit, the white corpuscles can be seen flattening themselves against the walls of capillary bloodvessels and gradually passing through them into the tissues around; projecting first a small portion beyond the

outline of the vessel, and then going through a series of hour-glass shapes, in which the part external to the vessel becomes larger and the part within becomes smaller, until the whole corpuscle has passed through. This process is called *diapedesis*. It was first discovered by Augustus Waller, but remained unverified for a number of years, and was subsequently rediscovered by Cohnheim, who pointed out its great pathological importance. The white corpuscles originate in the lymphatic glands, in the spleen, in retiform or lymphoid tissue distributed through the body, and in the marrow of bones. They have their origin in the solid tissues, and many of them, as we have seen, return to these.

FIG. 5.—Leucocytes escaping from a capillary blood-vessel in mesentery of rabbit. Elastic and white fibres of connective tissue, as well as the structure of the vessel, are also seen.

Several varieties or conditions of white corpuscles have been observed, and appear to indicate differences of source, function, age, or destination. Sherrington distinguishes in the dog (1) the *finely granular* with the nucleus obscured and variable, (2) the *coarsely granular* of large size, liable, like the first, to amoeboid changes of shape, and with granules well-defined, stained yellow by osmic acid vapour, (3) the *small hyaline* with spherical nucleus and small amount of clear surrounding protoplasm retaining the spheroidal shape, and (4) the *large hyaline*, with less regular nucleus and larger amount of rather clear protoplasm.[1]

The corpuscles of non-mammalian vertebrates. There is a broad distinction between the blood of mammals and that of all other vertebrates, for whereas the red corpuscles are always circular in mammals (save only in the camelidae which have them oval), and are in the normal adult condition devoid of nucleus, they are, in other vertebrates, always oval and always provided with a single distinct oval nucleus occupying the centre. The nucleus is devoid of colouring matter, and the coloured substance of the disc in which it lies is of the same ductile character as the mammalian disc. When, in addition, it is considered that mammalian red corpuscles are, in the young embryo, nucleated, and that an occasional nucleated corpuscle may be found even in adult mammals, it seems impossible to doubt that the mammalian red corpuscle is homologous with the non-

[1] Consult for details and bibliography Sherrington, *Royal Society Proceedings*, February, 1894.

mammalian, and that it is the nucleus, not the surrounding disc, which is fugitive in mammals.

The largest red corpuscles are found in the amphibia, the long diameter measuring in Proteus anguineus $\frac{1}{400}$th inch, and in the frog $\frac{1}{1100}$th. In fishes and in reptiles, both of which are groups embracing forms widely different in structure, it would be difficult to lay down a rule according to which the size of the corpuscles varies. In birds, which are a compact group, the ostrich would appear to have them largest, namely, with a long diameter estimated at $\frac{1}{1649}$th inch, and the humming bird to have them smallest, with a long diameter of $\frac{1}{2066}$th.

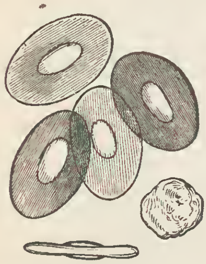


FIG. 6. — BLOOD-CORPUSCLES OF FROG, viz., four red corpuscles in full view, one in profile, and one white corpuscle.

In mammals the largest diameter is found in the elephant, $\frac{1}{2745}$th inch; and smallest in the smallest ruminant, the napu or tragulus, $\frac{1}{12325}$th inch.

Other bodies besides the red and white corpuscles have been described as occurring in the blood. The invisible corpuscle of Norris is a body of the same size and shape as the red corpuscle, but without the colour. Such corpuscles Norris maintains to exist in the circulating blood. Undoubtedly, by very slight changes in the blood, some of the red corpuscles lose their colouring matter and become difficult to see, while others remain unaffected, or become darker; and even supposing that the evidence is not sufficient to support the contention of Norris that invisible discs exist in the circulation, it is of great importance to recognize that the red corpuscles are thus dissimilar in nature, as this points to a difference, according to age, in their utility as carriers of oxygen. The *blood-plate* of Bizzozero is a similar structure of smaller size, and is probably the result of divided red corpuscles losing their colouring matter. *Elementary granules* of Zimmerman are small particles, some of which have been set free by the breaking up of white corpuscles, and are liable to congregate as granular masses in blood outside the body, while others are doubtless particles separated from red corpuscles after the fashion above pointed out. This is probably the nature of those termed *haematoblasts* by Hayem, and looked on by him as origins of the red corpuscles.

The colourless nuclei of red corpuscles in embryos and non-mammalian adults present a strong objection to any theory of the development of the red corpuscle which does not derive it from a nucleated corpuscle afterwards losing its nucleus. The theory formerly almost universally held, that red corpuscles are formed from certain of the white corpuscles, is not open to this grave objection. As shown by the researches of Neumann, Bizzozero, and Schäfer, another source of red corpuscles in the adult is the red marrow of the bones. In the early embryo, red blood-corpuscles are produced by the division of nucleated corpuscles

within anastomosing cell-walls which are concerned in the first formation of bloodvessels in the area vasculosa.

THE CONNECTIVE TISSUES.

The connective or binding tissues include a large variety of structures differing in appearance and firmness, the firmer varieties forming protective sheaths and uniting bands, by means of which the whole body is joined together, while the finer descriptions not only surround the elements of texture and special structures of organs, but are closely associated with their nutrition. They all consist of corpuscles embedded in matrix or deposited substance, and to the nature of this the different varieties owe their physical characters. The deposited substance is of two kinds, gelatiniferous and yellow-elastic, and each of these occurs in fibrous and homogeneous forms.

Fig. 7. — Connective Tissue from orbit of ox, exhibiting corpuscles of various shapes, straight white fibres, and curled elastic fibres.

Gelatiniferous substance, as it exists in the body, is of unknown chemical nature, but by prolonged boiling is dissolved, being converted into gelatine. It is often found homogeneous, as in structureless membranes and the most superficial part of the true skin, and this condition passes by gradual transition into the fibrous, which is termed *white fibrous tissue*. White fibres, as seen under the microscope, vary from the faintest fibrillation of an otherwise homogeneous substance to distinct threads, presenting a double contour, but indefinite in length, which shade away into finer substance. Broader bands which at first seem structureless may be resolved by manipulation into bundles of finer fibres. White fibres may take irregular courses in different directions, felting with one another, or they may be arranged in parallel bundles which are sometimes quite straight, as in tendon, and sometimes present regular angular undulations reflecting the light with satin-like lustre in different directions from different parts of their curves. On addition of acetic acid, they swell up and become invisible under the microscope, but they resume much of their original appearance when the acetic acid is washed away.

Structures composed of white fibrous tissues, *e.g.* the ordinary ligaments

and tendons, have a definite length and are inextensible; that is to say, they cannot be stretched beyond their proper length without damage to their tissue. The definite character of the movements of joints is dependent on this property, and were it not for the same property in tendons, there would be a great waste of power by muscular contraction expending its energy in lengthening tendons instead of moving the bones to which they are attached.

FIG. 8. — DEEP FASCIA OR APONEUROSIS over biceps flexor radialis muscle. Bundles of undulating white fibres; fusiform and amoeboid corpuscles.

Yellow-elastic substance gets the name elastic from having the properties of extensibility and resilience like india-rubber. In the innermost coat of arteries there is a good example of a homogeneous membranous arrangement of this substance, while, in the middle and outer coats there are laminae exhibiting a transition from membranes with frequent perforations to firm networks of fibres membranously arranged. There are two very different dispositions of yellow-elastic fibres. In one, the fibres are scattered through white fibrous tissue, and each fibre exhibits highly irregular circular curves, totally distinct in direction from all the others. Such fibres are found in great abundance in the cutis vera and subcutaneous tissue, under the serous membranes, particularly the pleura, and in other situations. The other disposition of yellow-elastic fibres occurs when they form the main substance

FIG. 9. — YELLOW-ELASTIC TISSUE. *a*, Longitudinal section of ligamentum subflavum; *b*, transverse section of ligamentum subflavum; *c*, independent coiled fibres in the pleura.

of the tissue. The fibres then take a straight course in parallel bundles; and, when it is sought to separate them, they are found to be netted together, so that they cannot be thoroughly individualized. Transverse sections bring out the netted arrangement, short blocks of thick fibres being seen under the microscope, connected by thinner bands, which, being pressed out of their original position, tend to curl up. So also by teasing out yellow-elastic tissue the torn liberated ends curl up; but the curling is produced by the manipulation. The thick fibres are not of uniform firmness; and in yellow-elastic fibrous tissue, which has been kept for a length of time and frequently stretched, they tend to give way on one side, exhibiting closely set transverse cracks, reminding one of india-rubber tubes long in use. The ligamenta subflava uniting the laminae of the vertebrae consist of yellow-elastic fibrous tissue. The only other example of this tissue in the human subject is the crico-thyroid membrane, and even it has a larger amount of white fibres intermixed with the yellow. But in quadrupeds the largest mass of this substance is the *ligamentum nuchae*, and in animals with heavy viscera, like the ox, the sheep, and the horse, there is a sheet of it superficial to the muscular wall of the abdomen.

Fig. 10.—Fibres from Ligamentum Nuchae of Horse, from a long-kept specimen. They present serial transverse cracks on one side.

The nucleated corpuscles found in the connective tissues may be broadly distinguished into two kinds—the migratory or unwalled, and the branched or walled. The *migratory* or *amoeboid* corpuscles or *leucocytes* are some of them identical with those found in the circulation, which, as has been already described, are capable of leaving the vessels and worming their way into the tissues; others are flattened out and have irregular forms, with a tendency to send out processes, and have the nucleus oval. Every stage of gradation exists from the one of these forms to the other, and there seems no reason whatever to doubt that the larger and flatter are derived from the smaller and rounder, and in turn pass into corpuscles, walled and branched. The walled and branched corpuscles are those to which the expression *connective-tissue corpuscles* is usually confined. They have a variable number of branches which sometimes anastomose with the branches of other corpuscles, but more frequently taper away into linear processes or tails. The most common form of all is the spindle-shaped corpuscle with two tails elongated in opposite directions, and such corpuscles are seen in all gradations of development from unwalled corpuscles. Oval nuclei without protoplasm occur in certain modifications of the connective tissues. They are found in homogeneous matrix, *e.g.* in synovial membranes and in the fine sheaths of the primitive bundles of nerves.

The different varieties of connective tissues composed of corpuscles and white substance, with or without admixture of yellow-elastic fibres, are retiform tissue, areolar tissue, fascia, aponeurosis, ligament, and tendon.

Retiform, lymphoid, or adenoid tissue is the variety of connective tissue in which there is the greatest abundance of corpuscular elements. Its matrix presents a very delicate gelatiniferous substance, which often appears in the lymphatic glands to consist of a network of stellate cell-walls whose branches intercommunicate to form the threads bounding the meshes, while the interspaces are more or less crowded with leucocytes of different sizes which proliferate within it. It is a tissue found in greatest abundance in the lymphatic glands, and occurs also diffused in thin layers, surrounding secreting tubes or lobules.

Fig. 11.—Subcutaneous Connective Tissue from embryo duck, showing corpuscles with anastomosing branches. *a*, A nucleus; *b*, a branch. (Böhm and v. Davidoff.)

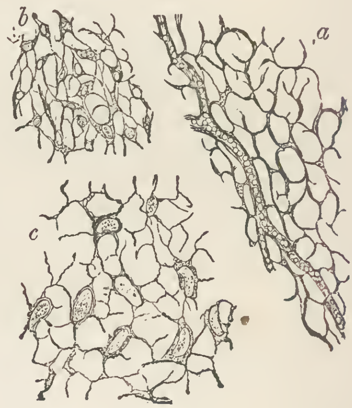


Fig. 12.—Retiform Tissue: *a*, from mesenteric gland of cat; *b*, from mesenteric gland of kitten before birth; *c*, from thymus of salamandra maculata. (Toldt.)

Areolar tissue consists of delicate gelatiniferous substance exhibiting delicate fibres and bundles of fibres taking different directions, so as to form a felted arrangement and leave irregular meshes or areae between them, which are the cells or spaces to which allusion was made when formerly it was termed *cellular tissue;* it is especially to this variety that the expression *connective tissue* applies.

Fascia is a firmer variety of felted white fibrous tissue spread out to form a sheet or membrane devoid of lustre. All fasciae are continuous with looser areolar tissue on one or both sides, and thick sheets are often capable of being artificially divided into an indefinite number of laminae. Fascia has always a certain admixture of coiled yellow-elastic fibres in its substance.

Aponeurosis is a term properly applied to sheets of white fibrous tissue with lustre depending on the regularity of the arrangement of the bundles,

often finely undulated, which are either parallel to one another or in two or three sets regularly crossing one another. Two kinds are recognized, namely, aponeurosis of *protection*, and aponeurosis of *insertion*. The same protective sheet may be at one part regular and lustrous and at another felted and dull, which leads to the words aponeurosis and fascia being sometimes used indifferently with reference to one structure. Thus, we speak of the aponeurosis of the lower limb or the fascia lata. Aponeurosis of insertion differs in being continuous with muscular fibres, and while in structure identical with aponeurosis of protection, is on the other hand a membranous tendon in general appearance.

Ligament and Tendon are the two strongest varieties of white fibrous tissue, and agree in having the bundles of white fibres running in one

FIG. 13. — TENDON: *a*, *b*, *c*, from boiled flexor tendon of sheep's trotter, showing quadrate scales, *a*, with the edges slightly folded, *b*, seen edgeways united by a thread, *c*, in full face with elongated nuclei in continuous thread, one behind each scale; *d*, *e*, *f*, *g*, normal appearances from rat's tail, *d* and *f*, with the scales seen edgeways, *e* and *g*, in full face with their flat circular nuclei; *h*, *i*, abnormal appearances from rat's tail, the whole chain being cylindrical and stained deeply with carmine; *k*, human, from thick tendon of limb, large elongated nuclei deeply stained and united by a thread.

direction. But ligaments in the human body have not as great lustre as tendon, and during life tendons may snap abruptly, as in rupture of the tendo Achillis, while ligaments tear in ragged fashion, so that sprains are often difficult to heal.

Tendon has in addition certain structural peculiarities of its own. It is surrounded by a sheath of areolar tissue containing nerves, and in transverse section is seen to consist of separate bundles with finer septa between them. The separate bundles of white fibrous tissue exhibit a mass which may be easily made to show longitudinal fibrillation, but which is apparently structureless when its parts are not displaced. Each bundle has laid against it and partially surrounding it a linear series of delicate flat cells or stainable scales more or less distinctly quadrate in shape with circular nuclei. These are the *quadrate cells of Ranvier*, and may be easily

seen in position in the tendons of the tails of small animals, such as rats, which do not require sections for their examination. At the back of each scale is a longitudinal structure easily stained, described by Boll as an elastic band, alleged by him to have been mistaken sometimes for the nucleus, but considered by Ranvier as a crest. I find it to consist of elongated corpuscles consisting chiefly of nucleus, united in linear series by a thread of connection. These chains are far more easily distinguished in the human subject than the quadrate scales.[1]

Medullated nerve-fibres breaking up into branched structures in tendons near their junction with muscle will be referred to in connection with muscular nerve-supply.

Adipose tissue. The tissue which is commonly known as fat is technically termed adipose tissue, the word fat being more properly used to signify the solid condition of an oil. Adipose tissue consists of groups of microscopic vesicles containing oil and supported by a delicate web of connective tissue. Adipose vesicles are mostly from $\frac{1}{300}$th to $\frac{1}{600}$th of an

a *b* *c* *d*

Fig. 14.—Adipose Tissue: *a*, in the unaltered state, the vesicles full of oil and lying among fine white fibres; *b*, stained and cleared from oil, some of the vesicles showing the circular flat nucleus, smaller nuclei of leucocytes scattered about, and a capillary with its oval nuclei brought into view; *c*, from foetus of five months, shows a group of germinal corpuscles as yet free from oil, and four converted into vesicles by accumulation of oil; *d*, from emaciated adult, showing withered vesicles, and others in different stages of formation from leucocytes.

inch in diameter and are rounded in form, or sufficiently closely packed together to have their sides somewhat flattened one against another. They are generally arranged in little clumps or grains separated by loose connective tissue from others, and these smaller grains are often collected into larger lobules. Though adipose tissue is but poorly vascular, it is better supplied with bloodvessels than is connective tissue, and each little clump of vesicles has a capillary distribution separated by non-vascular

[1] The nucleated thread appears to me to be the fundamental part of the arrangement which is never absent. A specimen is figured from a rat's tail in which the nuclei were not only exaggerated in size, but united by a thick protoplasmic thread, while the scales were absent.

substance from the vessels of the others. If it be carefully stained with carmine, and the oil be then removed from it by chloroform or some other solvent, a number of nuclei will be seen in every patch of vesicles, some of them oval and belonging to the capillary walls, while others are circular, with or without adherent protoplasm, and belong one to each vesicle. The solidity of adipose tissue depends on the walls of the vesicles, together with their surroundings, being saturated with watery fluid, with which the oil cannot mix. But if a piece of adipose tissue from the human subject be exposed on a plate, the watery fluid evaporates, and the oil impregnates the shrivelled tissue and soon gathers in a pool. This does not occur with the adipose tissue of the sheep, because in it the oil in the vesicles is solidified at the ordinary temperature of the air.

Adipose vesicles make their appearance early in the fifth month of foetal life. Previous to that date glycogen is abundant in the tissues, but it subsequently diminishes in quantity as adipose tissue becomes developed. Originally the adipose vesicles are rounded unwalled nucleated corpuscles, leucocytes, in fact, as may be seen to advantage by examining the mesentery of a kitten at birth, when little heaps of these corpuscles can be seen occupying the positions afterwards occupied by collections of adipose vesicles. The oil appears in them first in minute molecules, some of which get larger, as may be judged from other corpuscles containing one or more distinct globules, besides minuter particles. The globules run together into one, while the protoplasm is changed in character, being gradually converted into the wall of a vesicle, and the nucleus is thrown to one side and ultimately flattened. This process can be studied with advantage not only in the foetus, but in the bodies of emaciated adults; and the number of corpuscles which may in such circumstances be sometimes seen with the nucleus and protoplasm distinct seems to point to increased activity of the tissues in connection with the absorption of oil into the circulation.

Fig. 15.—Portion of Fat Lobule from axilla of a much emaciated young man. (Toldt.)

CARTILAGE.

Cartilage is sometimes classed with the connective tissues and its close relation to these is shown in the changes which it undergoes in ossification, in the structure of intervertebral discs, and in other ways. But typical or hyaline cartilage is a texture with very distinctive features.

It is called *temporary* or *permanent* according as it is destined to be converted into bone or to remain as cartilage till adult life. Among the more important masses thus remaining in the adult may be mentioned the costal cartilages, the articular cartilages, and those of the larynx, trachea, and other air-tubes.

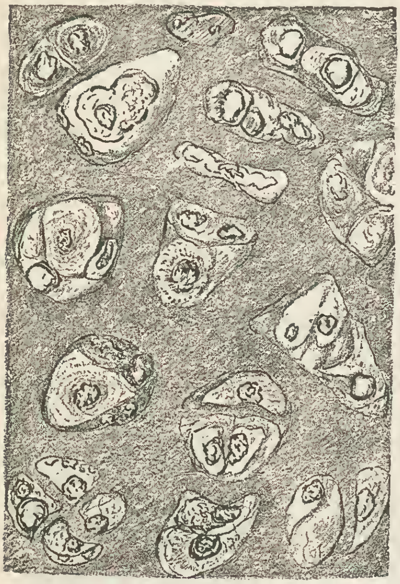


Fig. 16.—Costal Cartilage, human. At the upper right-hand corner degeneration of corpuscles has set in.

Hyaline cartilage consists of incapsuled corpuscles lying in a clear or hyaline matrix which, on boiling, yields principally a substance called chondrin, resembling gelatin in being soluble in hot water and forming a jelly on cooling, but differing somewhat in composition and in respect that while, like gelatin, it is precipitated from solution by tannin, it is likewise precipitated by acids, alum and sugar-of-lead, which do not precipitate gelatin. This chondriniferous matrix is the part which gives to cartilage its physical characters, making it firm, tough, flexible, springing back when bent, and breaking with a somewhat vitreous fracture. It often exhibits under the microscope a faint indication of fibres, and more constantly a slightly granular appearance, most evident in the parts furthest removed from the corpuscles, which are also the parts most darkened by osmic acid, probably from a certain amount of oily matter being present.[1]

The corpuscles lie in capsules of the same substance as the rest of the matrix, only firmer and capable of being isolated by softening of the matrix by reagents. The corpuscles, when young and active, fill the capsules. Their protoplasm is granular, the nucleus distinct; and there is often a clear nucleolus, staining very dark with osmic acid. Two, three, or more corpuscles may be present in one capsule, while near it there may be a similar group, the members of which are each inclosed in a distinct capsule separated by bars of matrix from the others; or an imperfect bar may be seen partially separating one capsule from another. Thus, it is evident that cartilage increases in size by growth throughout, the corpuscles multiplying, their capsules dividing, and new matrix being afterwards thrown out between them, so that they are forced apart,

[1] Very remarkable complexities of matrix connected with sap-currents and fibrillation have been brought into view by special methods. For a full account of these and the literature of the subject, see Wolters in *Archiv für Mikrosk. Anat.*, 1891, Vol. xxxvii., p. 492.

every such action in the deep part of a block necessitating movements in all the parts around. Although in adult fishes, and in certain stages of the growth of human bones, cartilage occurs with the capsules unicorpuscular and evenly disseminated, more usually the capsules, whether containing one or more corpuscles, are arranged in groups. They may be of rounded form, but are more frequently subangular, the individuals belonging to one group not being sufficiently separated to swell equally in every direction, but presenting flattened sides to the other members of the group. Another condition is common in the human foetus in parts at some distance from an ossifying surface, and likewise is found in permanent cartilages of various animals, namely, capsules linearly elongated and spindle-shaped, containing two, three, or more corpuscles, and, mixed with these, linear spindle-shaped groups of unicorpuscular capsules, the terminal members of each group having an elongated triangular form. These linear arrangements cross each other, pointing in every direction, so that together they lead by their growth to increased size of the block in all diameters.

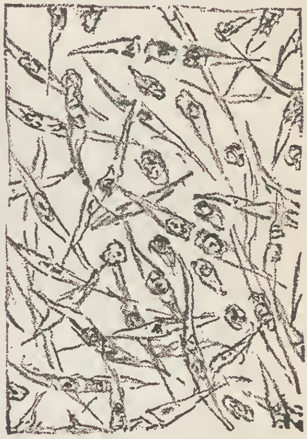


Fig. 17.—Cartilage with Spindle shaped Capsules from lower end of femur of child at birth.

Cartilage is a texture devoid both of vessels and nerves. It is, however, generally surrounded by a special fibrous covering containing bloodvessels, the *perichondrium*. But where cartilage is continuous with bone there is no perichondrium, neither is there any on the free surfaces entering into the formation of joints. Large masses of cartilage are penetrated by canals containing bloodvessels, but the walls of the vessels have always connective tissue between them and the cartilage.

The **costal cartilages** are remarkable for the large size of their corpuscles and oval capsules. The corpuscles in one capsule vary in number up to six, seven, or more. Both corpuscles and capsules are largest in the centre of the cartilage, while at the circumference they are not only small, but flattened in a direction parallel to the perichondrium, as if the immediate pressure of that inactive membrane interfered with their growth more than did the dense mass of matrix penetrated by nutritive currents. As age advances, the matrix of costal cartilages becomes granular from calcareous deposit, beginning mostly in the heart of the bar, while true bone is occasionally developed in the perichondrium. At a much earlier period the corpuscles are subject to degeneration, their protoplasm becoming coarsely granular and more easily stained with carmine, while dense masses form within them, not easily stained, waxy in appearance, but not affected by iodine, and these, as they enlarge, become hollowed into capsules (Fig. 16).

Articular cartilage is the permanent hyaline cartilage which coats the opposed surfaces of bones united by synovial articulation. It forms a covering which is thickest in the centre when the surface is convex, and thinner in the centre than at the circumference when the surface is concave. It has a more milky appearance than most cartilage, and breaks across with a vertically fibrous fracture;

Fig. 18. — Articular Cartilage, vertical section, with calcified layer beneath.

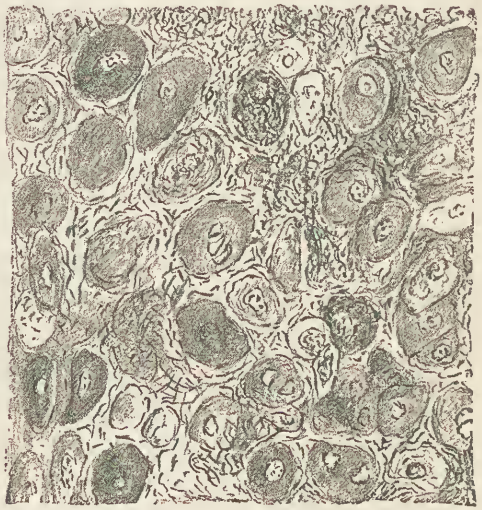


Fig. 19. — Yellow Cartilage, from human epiglottis.

and this fibrous appearance becomes more notable after prolonged maceration, and after certain pathological changes. It is apparently due to the vertical arrangement of the corpuscles in great part of the depth, the matrix being firmer in the solid parts between rows of corpuscles. In the deepest part the capsules are oval; superficial to this they become elongated, and one finds elongated capsules containing linearly placed corpuscles, together with linear rows of shorter capsules, up to near the free surface, where the capsules become flattened out parallel with the surface. A section peeled from the surface shows corpuscles grouped together, often a number in one capsule, something like costal cartilage, but differing in respect that the corpuscles and capsules are flat. In every joint in the adult, the articular cartilage is separated from the osseous texture beneath, a thin calcified layer presenting unbranched cavities in a uniformly calcified matrix. It is strange that writers have sometimes been slow to recognize this layer, seeing that it persists in the macerated bone, forming the peculiar crust of the articular surfaces, destitute of orifices of the kind which pierce the surfaces of true bone.

Yellow or **reticular cartilage** is seen to most advantage in the epiglottis. It differs from hyaline cartilage in having within the matrix a deposit of elastic substance arranged more or less distinctly in felted fibres, with granules interspersed. This yellow deposit does not invade the capsules, and in preparing sections, an occasional capsule may be rolled out in front of the knife, leaving the space which contained it empty. This form of cartilage occurs in the human subject in the epiglottis, cornicula laryngis, Eustachian tube and the pinna of the ear.

Fibro-cartilage. Under this name several tissues considerably differing one from another are usually described. They will be again referred to

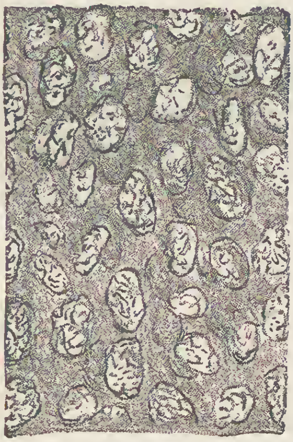


Fig. 20.—Embryonic Cartilage, from vertebral column of human embryo two months old. Matrix is deposited, but there are no capsules.

Fig. 21.—Capsular Cartilage, from ear of bat. The capsules contain clear fluid, and are placed close together.

in connection with the general anatomy of the articulations, under the heads of fibro-plates, incomplete joints, and intervertebral discs.

Embryonic cartilage. In the early embryo, cartilage is at first nearly purely corpuscular, there being only sufficient matrix to cement the corpuscles together but no appearance of proper capsules.

Capsular cartilage. Contrasting with the embryonic there is another kind of cartilage found particularly in the pinna of the ear in small mammals. It consists of empty capsules placed close together and containing no vestige of corpuscular substance. No such texture occurs in the human subject.

BONE.

Bone, or osseous tissue, is so termed from being the principal texture entering into the composition of the skeletal structures called bones. A bone is an organ in which there are also present other textures. It is permeated by bloodvessels; it contains marrow; it is surrounded by a

fibrous membrane, the *periosteum,* in which the arteries ramify before entering the osseous tissue; and it may have articular cartilages for articulating with other bones. The macerated and dried bones used for study are not merely deprived of all these textures, but have likewise lost the corpuscular element of the osseous tissue and consist of mere calcified matrix.

General characters. Bone is very generally classified with the connective tissues. Like them it consists essentially of branched corpuscles embedded in gelatiniferous matrix; but the matrix is impregnated with mineral matter to the extent of two thirds of its weight. It has been estimated as containing of phosphate of lime 57 per cent., carbonate of lime 8 per cent., and phosphate of magnesia and fluoride of calcium at the rate on an average of 1 per cent. each. The animal matter may be removed by burning in the fire, while the calcined remains preserve the original form and apparent structure. So also, if the mineral matter be removed by long steeping in dilute hydrochloric acid, the bone will still preserve its size, form, and texture, though rendered flexible, shrivelling up when dried, and recovering its size when steeped in water. These properties, as well as the translucence of the matrix when examined in thin sections, show how intimately the mineral and animal constituents are commingled.

Bone is highly elastic, and its elasticity gives strength and spring, especially in association with such curves as are exemplified in the ribs, the clavicle, the femur, and other parts of the skeleton. It presents two principal varieties, the *compact* and the *cancellated.* Compact bone is in solid mass, while cancellated bone is arranged in spicules and delicate plates so as to leave spaces filled with marrow, the whole forming a spongy mass easily crushed, and never appearing on the surface, but always covered in by at least a thin crust of compact bone. Cancellated tissue in the human subject and mammals generally is composed more of spicules than of plates, but well-marked plates are often met with on the sides of medullary cavities; and a third arrangement is seen in the *diplöe* or soft tissues between the outer and inner tables of the skull, produced by structure peculiar to compact bone persisting between labyrinths of marrow-spaces eaten out by absorption. The spicules of cancellated tissue in the larger bones present a distinct tendency to definite arrangement. In the upper parts of the femur and humerus, they form lines springing from the compact tissue of the shaft and spreading out in interlacing arches to end above at considerable angles to the surface. In the vertebrae the principal lines of direction are vertical and horizontal; and generally, the spicules in different bones may be described as disposed in such a manner as to combine strength and lightness, an advantage which is also gained in the shafts of the long bones by the compact tissue being in the form of a tube round the marrow-cavity.

The surfaces of dry bones are covered all over with minute orifices,

just visible to the naked eye, for the entrance of bloodvessels from the periosteum; and these, when there is any considerable thickness of compact tissue, are sloped, and enter from elongated grooves running in one direction; but over cancellated tissue they are irregular in size, owing to some of them being larger, and they have not such obliquity.

Near the articular extremities of the long bones of the limbs, on the posterior surfaces of the bodies of vertebrae, and in other situations, foramina of greater size occur for the exit of veins. Bones possessed of a medullary cavity present in addition a foramen in the shaft, constant in position, the *arterial* or *nutrient foramen*, containing for the supply of the marrow and adjacent walls of bone the so-called *nutrient artery* and a small vein.

Fleshy origins of muscles cause no mark on bone, the muscular fibres being attached to the outer layer of the periosteum; but where tendon has been attached there is roughness and elevation, because the tendinous fibres are continuous with the substance of the bone. The articular surfaces of dry bones have a characteristic appearance, being composed of calcified cartilage (p. 22).

Microscopic structure. In thin slices under the microscope, all bone exhibits a clear translucent calcified matrix, and in it *lacunae* and *canaliculi*. Lacunae are small spaces, each of which, in the recent state, is occupied by a single *bone-corpuscle*. Canaliculi are fine thread-like canals which come off from the lacunae, sometimes in numbers fewer than a dozen, but in other instances, as in compact tissue in the adult, so numerously as to be uncountable. They are seen to advantage in ground sections of dry bone so mounted that the air with which they have become filled is not displaced. They then have the appearance of closely set fine black branching lines continuous with the canaliculi of neighbouring lacunae, or opening on the surface, or into one of the canals about to be described, called Haversian. The lacunae vary in size and shape in different situations, but may measure on an average $\frac{1}{2000}$th of an inch in their longest diameter. The bone-corpuscles fill the lacunae in which they lie, and send branches into the canaliculi; but the branches do not appear to occupy the canaliculi permanently in their whole extent. Lacunae and canaliculi can still be brought into view after decalcification; and some observers have even been able to isolate them, showing that their walls are firmer than the rest of the matrix.

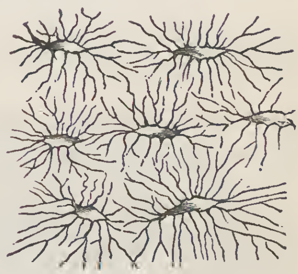


FIG. 22.—LACUNAE AND CANALICULI. The canaliculi may communicate much more freely, but this is not always the case.

Compact osseous tissue presents additional arrangements besides those which are common to all bone and sufficient for fine spicules or laminae embedded in soft tissues. Minute canals entering from the orifices on

the surface pervade its whole extent, running nearly parallel with the surface, and united by oblique and transverse connecting branches into a network occupied throughout with minute bloodvessels. They are called *Haversian canals,* after Clopton Havers, who noted their existence in 1689, but was ignorant of their contents. They vary very considerably in size, but the greater number of those running longitudinally are about $\frac{1}{500}$th of an inch in diameter, while the connecting branches are often smaller and may even be less than $\frac{1}{2000}$th of an inch. In the neighbourhood of medullary cavities or cancellated tissue, larger Haversian canals are formed containing an arteriole and a venous radicle, but those in thoroughly compact tissue contain only one minute vessel belonging to a capillary network corresponding with the network of canals. The substance of the compact tissue is laminated; and in a transverse section of the shaft of a long bone the arrangement of the lamination is brought into view. The lacunae are seen to be arranged in concentric layers, and to be flattened in the planes of lamination with the greater number of their canaliculi passing outwards and inwards to communicate with those in the layers adjacent; and several lamellae, even as many as six, may be counted between successive layers. Four kinds of lamination are distinguished, viz.: (1) the *peripheral* or *primary,* surrounding the bone and parallel to the periosteum, most abundant in young bones; (2) the *Haversian systems,* forming concentric rings round the Haversian canals and composing much the larger part of the adult tissue; (3) the *internal* or *perimedullary,* lining

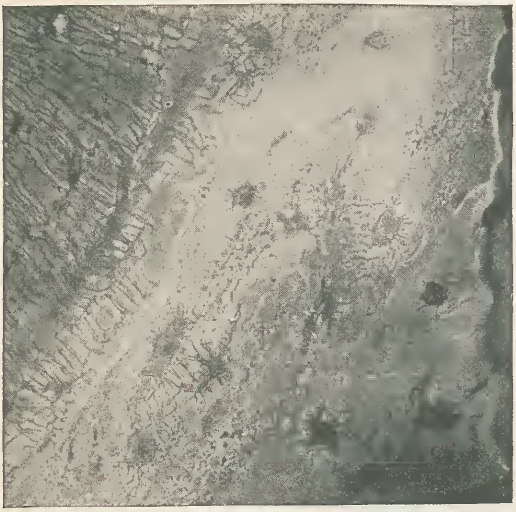


FIG. 23.—SECTION OF OX BONE, showing nucleated bone-corpuscles, also anastomosing canaliculi in the outer rings of a Haversian system. Prepared by Mr. Walter Colquhoun. Photographed by Dr. Thomas Reid.

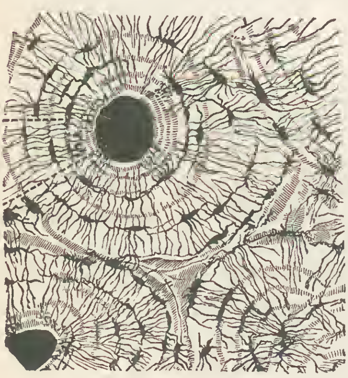


FIG. 24.—TRANSVERSE SECTION OF COMPACT TISSUES of humerus, showing concentric arrangement of lacunae and lamellae around Haversian canals. (Sharpey.)

the medullary cavities; (4) the *intermediary* or *interstitial*, filling up the spaces between the Haversian systems, and consisting of portions of

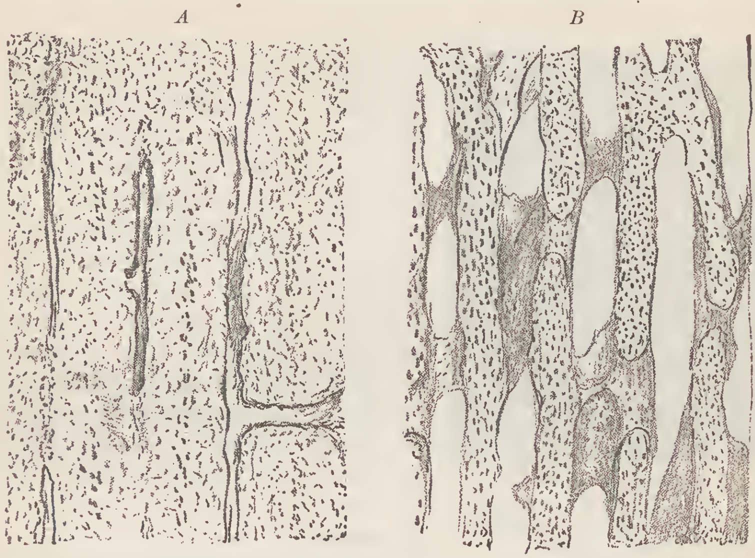


FIG. 25. — LONGITUDINAL SECTIONS FROM SHAFT OF FEMUR, showing the arrangement of Haversian canals. *A*, Adult; *B*, at birth.

lamellae belonging to the first three kinds, the other parts of which have disappeared by absorption.

FIG. 26. — TRANSVERSE SECTION OF TIBIA OF HORSE. *a*, Haversian canal; *b*, Haversian space; *c*, absorption-space.

Although it has scarcely attracted sufficient attention, there can be no doubt that processes of absorption and redeposition of bone are, to a greater or less extent, continually going on, by which old lamellae are eaten into and new Haversian systems are laid down; for there are two kinds of spaces to be distinguished scattered through compact osseous tissue, one kind which may be termed *absorption-spaces*, having ragged edges traversing lamellae of different systems whose continuity they interrupt, and others, distinguishable as *Haversian spaces*, in which this ragged outline has begun to be lined by new lamellae, the outer rings of systems not yet developed to the extent of

closely surrounding the bloodvessels and thereby completing the Haversian canals. In adolescence the alternations of absorption and deposition may be studied with special care in horizontal sections of the ramus of the lower jaw, where the appearances seen completely corroborate Humphry's observations (p. 35). All the bones normally become more dense for a long time after middle life, the arrangement of the lamination at the same time becoming more complex. But as old age advances absorption gains the ascendency, and not only medullary cavities are enlarged, but the tables of the skull approach one to the other, while everywhere compact tissue exhibits enormous absorption-spaces or enlargements of the Haversian canals, which in the recent state contain masses of closely set, small, but by no means active corpuscles.

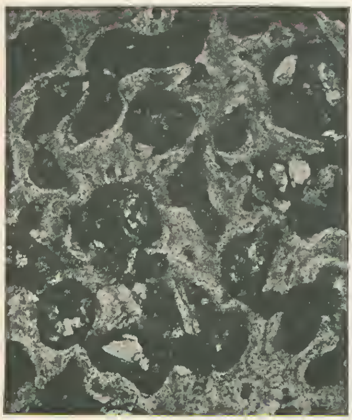


FIG. 27.—COMPACT OSSEOUS TISSUE OF OLD AGE. Transverse section of macerated femur. The dark parts are the absorption-spaces. The lacunae are barely visible. From photograph by Dr. Reid.

In sections of decalcified bone in which the soft tissues have been preserved, the Haversian spaces are lined with nucleated corpuscles regularly arranged; and similarly on the periosteal

FIG. 28.—MULTINUCLEAR CORPUSCLES from the youngest marrow-spaces of the flat bones of the human skull. $\frac{350}{1}$. (Kölliker.)

FIG. 29.—FIBROUS APPEARANCE OF MATRIX in wall of Haversian canal of decalcified human femur.

surface of growing bones a layer of nucleated corpuscles is engaged in the formation of the peripheral lamellae. In both situations the corpuscles are called *osteoblasts,* and may sometimes be seen in process of becoming embedded, one side fitting into a depression in the bone-substance and

having prolongations lying in canaliculi, while the other side is free. The absorption-spaces are similar in nature to irregular depressions found in the walls of growing medullary cavities and known as *pits of Howship*, but are inclosed passages destined, by being concentrically filled up, to be converted into Haversian spaces, and finally into complete Haversian systems. They present within them, like the pits of Howship, multinucleated corpuscular masses, such as were discovered independently by Kölliker and Robin in marrow, and called by the one *osteoclasts*, and by the other *myeloplaxes*. There seems no reason to doubt that these multinucleated masses are corpuscles which, proliferating in a confined space, are unable to part into separate individuals till they have made room by absorbing the bone around, and that then they break up into separate osteoblasts, to deposit bone anew. Except by such a process of alternate absorption and redeposit, it is impossible to account for the Haversian systems and the irregular arrangements of interstitial lamellae. Indeed, all the stages of the process can be seen. But such considerable sections are free from absorption-spaces, or contain them so very sparsely, that it is evident that bone-corpuscles have a very considerable duration. Absorption-spaces sometimes begin from a single lacuna in which may be seen a large corpuscle with several nuclei, sometimes by beaded enlargement of canaliculi, and sometimes at the sides of Haversian canals, or by pits in the side of marrow-cavities.

The matrix of osseous tissue is far from structureless. The arrangement in lamellae, already alluded to, becomes much more distinct when examined in decalcified specimens, and the lamellae then appear much more numerous than the rings of lacunae. Also the tissue between the lamellae seems as if arranged in closely set vertical septa, which in transverse section may present radiating lines extending from centre to circumference of a Haversian system. But when the section is allowed to dry, instead of distinct septa with regular spaces between, an appearance of a network with larger and smaller meshes comes into view. The lamellae resist shrivelling much more than the intervening substance. It was pointed out by Sharpey that in decalcified bone the lamellae exhibit an appearance of fine fibres, which he figured regularly decussating. Difficulty seems to be met with in verifying this; but the fibrous appearance is easily seen, not only in torn shreds but in vertical sections of compact tissue, if a fluid be employed which will make them firmer, such as a solution of tannin. They are then seen curving alongside of one another, those in one thin sheet decussating with those in another. The substance between the lamellae consists of fibres quitting one lamella and adhering to the next. The same fibrous appearance can be seen in plates of cancellated tissue, sometimes without decalcification.

Perforating fibres of Sharpey is the name given to fibres springing from a superficial lamella, piercing others and capable of being pulled out from them. Under the same name both white and elastic fibres have

been described; and Kölliker affirms that there is always air present in connection with them, showing that they have not been completely calcified but undergo shrivelling in the dry bone.

Periosteum, vessels and nerves. Periosteum, the membrane surrounding bone, is a fibrous structure containing bloodvessels and nerves, and presenting a layer of osteoblasts on its deep surface. But, at least on the shafts of long bones, it is a more regular and complex structure than seems yet to have been described by authors. Superficially it presents a strong white fibrous layer which swells up with acetic acid. This layer, when the bone is free from tendinous attachments, is disposed longitudinally, but may be strengthened by transverse or felted fibres over it. In it small arteries and veins ramify in company. More deeply there are thin sheets of firm tissue, not elastic, but not affected by acetic acid, exhibiting long fusiform corpuscles disposed in parallel lines. They are directed obliquely, those of one layer decussating with those of the other; and between the layers is a continuous capillary network with meshes similar to those made in the compact bone by the Haversian canals. Occupying the capillary meshes there are numerous irregularly-shaped corpuscles, and lastly, on the deep side of the decussating sheets, is the osteoblastic layer, which on an adult bone may present an appearance like an epithelium, while on a growing bone the corpuscles may be two or three deep.

Schäfer has figured a small artery, a large vein, a lymphatic, and a nerve in one section of a Haversian canal; but in the shafts and immediately beneath the articular cartilages of the great bones of the limbs there is only one vessel in each Haversian canal. The vessels form a meshwork like the canals in which they lie, and though their walls are strengthened by longitudinal fibres, as are those of the deep layer of periosteum from which they come, they ought to be regarded as capillaries. A little consideration will show that any other conclusion is highly improbable. The network of Haversian canals is obviously for the nutrition of the osseous tissue around, but an artery and vein in company indicate the nutrition of a territory beyond. Nerves are easily seen in the superficial structure of the periosteum, and have been traced by Kölliker in company with the medullary and other arteries into the interior, but there is no knowledge of other distribution than to the vascular walls.

Marrow is of two kinds, the *yellow*, filling medullary spaces of considerable size, and the *red*, occupying the smaller spaces in cancellated tissue. The yellow marrow owes its colour to adipose vesicles, and the red marrow owes its redness partly to blood and partly to corpuscles outside the bloodvessels. The supporting stroma is exceedingly slight, even the part in contact with the osseous walls, where it is sometimes distinguished as *endosteum* or medullary membrane and contains a larger number of bloodvessels to nourish the bone. The yellow marrow in wasted persons becomes gelatinous in appearance, and presents partially emptied fat-vesicles in very delicate stroma. Red marrow contains scattered

adipose vesicles and a large number of amoeboid corpuscles, most of them very similar to white blood-corpuscles, others with larger nuclei, some larger in size and some smaller, also red blood-corpuscles and nucleated corpuscles containing red colouring matter. Near the bone and in recesses where absorption is going on, there are multinucleated masses, such as have been already alluded to, the osteoclasts of Kölliker, engaged in the absorption of osseous matrix. There is no real distinction between yellow and red marrow, save that the red contains a smaller number of adipose vesicles, and a larger number of other corpuscles. The resemblance of these latter to the corpuscular elements in the lymphatic glands and splenic pulp is sufficient to favour the idea now generally held that the marrow is a source of development of both white and red corpuscles. Capillary bloodvessels form networks in the marrow which can readily be exhibited, but at places here and there they present imperfect walls, which allow, as I have seen in the rabbit, coloured injection to mingle with the corpuscles around.

Ossification. The greater number of the parts of the skeleton exist as cartilage before osseous tissue appears in them. This, however, is not a universal arrangement, and bones which do not pass through a cartilaginous condition, but make their first appearance in membrane, are called *membrane-bones.* Membrane-bones may be distinguished into two kinds: those which have no connection with cartilage, and those which are formed in proximity with it, but separated from it by perichondrium. Of the first sort are the roof-bones of the skull, viz., frontal, parietals, upper portions of the occipital, and the squamous parts of the temporals. But in reference to these it may be remarked that though, in the higher animals, the primordial cartilaginous cranium does not extend to their neighbourhood, yet, in some animals, as in fishes, it is complete, exhibiting a roof as well as sides and base. The lower jaw and the vomer may be taken as examples of bones which, in the human subject, appear on the surface of cartilage, but separated from it by perichondrium. It may be questioned if there is any radical difference between membrane-bones and others, although authors have given importance to the distinction. Not only is there much of the ossification of cartilage-bones periosteal in origin, but an osseous centre which has appeared in cartilage may extend into the fibrous tissue around, so as to be altogether embedded in it. This is the case with the processus gracilis of the human malleus, and notably so with the basi-occipital of osseous fishes. There are, however, two very distinct modes of ossification, one from membrane the other from cartilage.

Ossification from membrane is exceedingly simple, and the essential part of the process has already been described as it is seen in the formation of the Haversian systems and peripheral lamellae by the embedding of osteoblasts in mineralized matrix clear in appearance from the commencement. The same embedding of osteoblasts is seen in the ossifi-

cation of the roof-bones of the skull. A layer of nucleated corpuscles appears in the fibrous membrane in which ossification is about to take place, larger and more numerous than those proper to its own substance; and the mineralized substance is at first thrown round groups of them in radiating bars frequently united so as to make a network of bony matter; while the spaces and corpuscles between remain as the primitive marrow-spaces and their contents. At the ossifying margins, fibres push

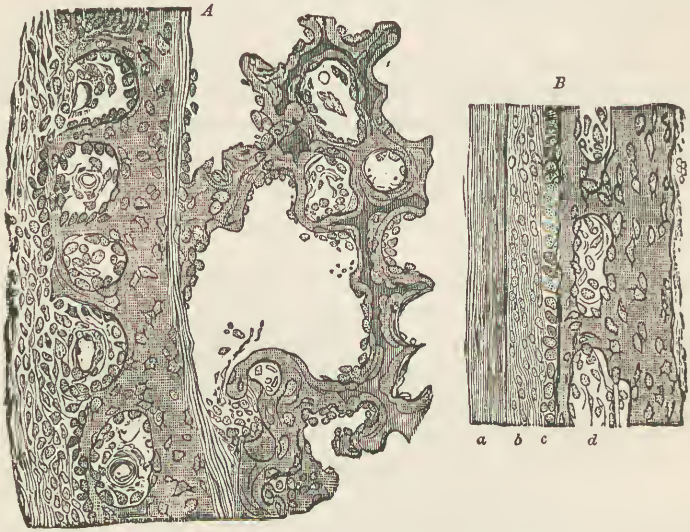


Fig. 30.—Ossification from Periosteum. Sections of femur of kitten before birth. *A*, Transverse section; *B*, longitudinal; *a* and *b*, outer and inner binding strata of periosteum; *c*, osteoblastic stratum; *d*, bone and marrow-spaces. (Toldt.)

straight out into the surrounding tissue, and are known as the *osteogenic fibres.* They appear to be connected with the fibrous character of the bone-matrix.

Ossification from cartilage exhibits a certain amount of variation in different circumstances. At the growing end of a shaft of bone in which ossification has already been proceeding for a length of time, the cartilage near the ossifying surface exhibits a series of modifications preparatory to undergoing conversion into bone. At a little distance from the ossifying surface, the cartilage-capsules are isolated, each containing one or more cartilage-corpuscles. Nearer the bone, the isolated capsules have been broken up into lozenge-shaped groups of small capsules, which, in turn, undergo further growth, so as to be converted into vertically placed rows of capsules, each of which is transversely elongated and contains one large corpuscle. Yet nearer to the ossifying surface the cartilage-capsules become rounded out so as to be as deep as they are broad, and proliferation of the corpuscles within them begins. Meanwhile changes have begun in the matrix between the capsules. It is rendered opaque by the deposition of granules of mineralized substance, and, after the

mineral matter has been removed by acid, it presents a somewhat fibrous appearance. This is termed the *granular layer*, and owing to the small amount of matrix in proportion to the bulk of its corpuscular substance, it is brittle, and is the part in which the mass of cartilage tends to

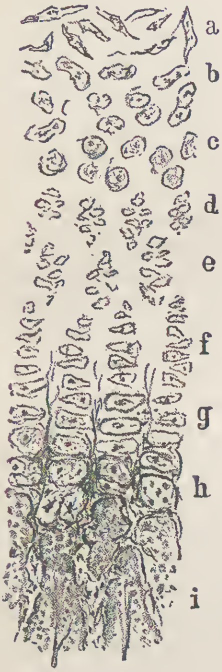


FIG. 31.

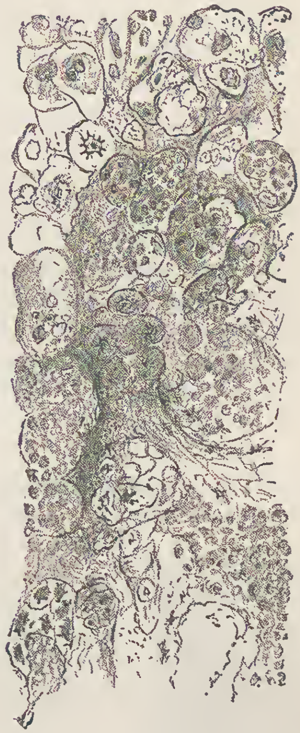


FIG. 32.

FIG. 31.—OSSIFYING EXTREMITY OF SHAFT OF FEMUR AT BIRTH, decalcified. *a*, Fusiform cartilage-capsules; *b*, the corpuscles become rounded and isolated; *c*, corpuscles large and separated by more matrix; *d*, each such corpuscle converted into a spindle-shaped group; *e*, each such group enlarged and more separated by matrix from others; *f*, the groups elongating, and the capsules enlarging transversely; *g*, the capsules greatly enlarged, the matrix diminished and presenting a pseudo-fibrous appearance—this is the granular layer, and it is here that the cartilage easily breaks away from the bone; *h*, capsules further enlarged, their corpuscles undergoing proliferation, and two of them represented as converted into branched bone-corpuscles by intra-capsular calcification; *i*, bone and two primitive marrow-spaces with two bloodvessels dilated above and lost among the marrow-cells. Semi-diagrammatic.

FIG. 32.—OSSIFICATION OF ASTRAGALUS AT BIRTH, decalcified. *a*, Cartilage; *b*, cartilage-capsules filled with numerous minute corpuscles, and one capsule containing a single corpuscle which has been surrounded with intra-capsular deposition of mineralized matrix; *c*, primitive marrow-spaces continuous with cartilage-capsules, also group of unicellular bone-lobules formed by intra-capsular deposit.

break asunder from the bone beneath. In the granular layer the capsules continue very generally to enlarge, and are filled with corpuscles which rapidly increase in number and diminish in size, till the capsules communicate with the marrow-spaces within the new bone, and the corpuscles which they contain are indistinguishable from the contents of those spaces; those of them which lie close to the mineralized matrix becoming spread

out against it and embedded as osteoblasts, while others are converted into marrow-cells.

Deeper down in the marrow-spaces, bloodvessels are found; but I have never seen the capillaries nearest to the ossifying edge ending in walled loops as sometimes figured, nor is it conceivable that they do so while vascularity is advancing. On the contrary, the walls widen out and die away so as to make the interiors of the vessels continuous with the corpuscular contents of the marrow-spaces. In some instances the contents of the cartilage-capsules, instead of freely proliferating, become branched, while mineralized deposit takes place within the capsule, as was originally shown by Kölliker in rachitis; and thus nodules of bone are formed corresponding in extent with cartilage-capsules, and having branched corpuscles in the interior.

At one time the view was advanced by Löven, and for a while gained support, that the cartilage-corpuscles degenerate and are removed, taking no part in the formation of bone. But this is certainly a mistake. I have often seen the cartilage-corpuscles taking part in ossification in the two ways now mentioned, viz., most frequently proliferating freely so as to produce a swarm of osteoblasts and marrow-cells, in other instances becoming embedded as branched corpuscles within a clear ball of mineralized matrix corresponding in extent with the capsule. The preparatory alterations in cartilage about to ossify are by no means always so complex as in the shafts of bones already considerably ossified. More generally the matrix becomes granular round the capsules without the capsules being arranged in columns. This is the case in the first deposit of mineralized matter in the shafts of long bones, in the vertebrae and other short bones, and in the epiphyses of the shafted bones.

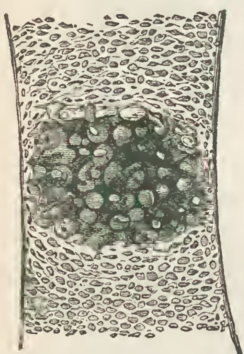


Fig. 33.—First Point of Calcification of cartilage in shaft of humerus of human embryo of two months. (Kölliker.)

In the first appearance of ossification in shafts of bones, the whole thickness of the shaft is converted into calcified cartilage, in the form of a network of globes containing the corpuscles imprisoned within them; and before this has become converted into true bone, already a sheath of bone derived from the periosteum surrounds it. Absorption of the mineralized walls of capsules, with proliferation of their contents, forthwith proceeds, and bloodvessels piercing from the periosteum enter the primitive marrow-spaces formed by inter-communication of capsules. In the epiphyses of the long bones and in the carpal and tarsal bones, the ossification is at first completely surrounded by cartilage pierced by channels containing bloodvessels, one or more of which are enlarged in connection with the first appearance of ossification. Thus, in all bone, vessels pass in from the outside, and in ossification from cartilage they

are continued into inter-communicating spaces, *primitive areolae*, formed by the breaking down of the partitions between neighbouring capsules. By the enlargement of areolae and concentric deposition of lamellae, Haversian systems are formed.

Enlargement of bones. Owing, no doubt, to its hardness, osseous tissue once deposited is incapable of expansion. At least this is the general rule in normal circumstances, and contrasts with the power of interstitial expansion manifest in cartilage. All extension of the size of an osseous mass is by additional substance deposited on its surface. This law of osseous growth was demonstrated, so far as the elongation of the shafts of bones was concerned, by John Hunter's experiment of inserting shot separated by a measured distance along a shaft of bone in a young animal. When, after the lapse of a certain time the bone is examined, the shot are found at exactly the original distance one from the other, while the distance from each to the extremities of the bone is increased, showing that new bone has been added at the extremities of the shaft. Duhamel was the first to place a metal ring round the humerus of a young pigeon, and to observe that as the animal grows, such a ring becomes covered superficially, and at last lies loose in the cavity in the interior of the bone; and though Duhamel himself believed in the growth of bone by interstitial additions expanding the tissue already laid down, the smoothness of the layers superficial to the ring in such experiments bear out the fact evident from the disposition of the peripheral lamellae, that new bone is added peripherally, while the older bone subjacent is absorbed so as to enlarge the medullary cavity.

Besides these main centres of ossification, bones often present supplementary centres which appear in masses of cartilage subject to pressure and strain. These are termed *epiphyses*, and, in the case of the long bones, the centre of ossification of the shaft is called the *diaphysis*, while there are generally epiphyses at the extremities. The epiphyses are late of uniting to the diaphysis, a very thin plate of cartilage persisting for a length of time between them. The shaft continues to lengthen as long as this thin layer of cartilage persists, new cartilage continuing to be formed nearly as rapidly as the part adjacent to the shaft is converted into bone; but, when by any undue irritation premature union of the shaft and epiphysis takes place (*synostosis*), the elongation at that end ceases. So also premature synostosis may take place in any of the sutures of the skull, and arrest enlargement along the line of union, the growing edges of the bones being obliterated. But probably the most convincing proof that bone does not increase in size by interstitial expansion is furnished by Humphry's experiments on the lower jaw. By passing wires through holes bored in the ramus of the jaw in the young pig, Humphry encircled the back part of the ramus with one ring, the fore part with another, and found, when the animal was killed after an interval, that the anterior ring was made loose in front by absorption of bone from the edge of

the ramus, while the hinder edge of the posterior ring was embedded by the formation of new bone behind it for a still greater distance than the anterior ring stood out loose (*Cambridge Philosophical Society Transactions*, XI.). Sections of young lower jaws under the microscope exhibit new layers added at the back of the ramus, while absorption is active in front. It may, however, be here remarked that there are circumstances in the growth of the teeth in both jaws, which point to some mode of expansion of those bones requiring further investigation. Thus, it may be noted that the permanent canine teeth have their crowns fully formed in situations from which they cannot be projected through the gums without previous separation of the teeth immediately in front and behind. It is also the case that the distance between the mental foramina of opposite sides increases after ossification of the symphysis of the lower jaw.

ARTICULATIONS.

The articulations by means of which the different parts of the skeleton are united may be divided into complete and incomplete.

Complete joints are characterized by two cartilaginous surfaces which move one on the other, unconnected by intervening substance, but held together by ligaments around. The structure of ligament and of articular cartilage has already been described. The breach of continuity between the articular cartilages is limited round about by *synovial membrane*, and is itself called the *synovial cavity*, *synovia*, or *synovial fluid* being the term applied to the substance which lubricates and gives a certain softness to the interior of the joint, without being in such quantity that any can be gathered.

The synovial membrane is continued from the margins of the articular surfaces to a certain slight extent on the periosteum, before being reflected on the deep aspect of the ligaments and other surrounding parts to the margins of the opposed articular surfaces. It is also, in some instances, prolonged a certain way on tendons or underneath muscle, resembling in such prolongations the separate *bursae mucosae* provided in different places for the gliding of muscles or integument on bone, and the *thecae* or separate synovial sheaths surrounding tendons bound down by fibrous bands. But the synovial membrane of a joint differs from such other pouches in not forming of itself a continuous shut sac. It is not continued over the surfaces of the articular cartilages, save only in the foetus, but is rather continuous with them. It is possessed of a network of bloodvessels, and these are continued for not more than the twentieth of an inch over the margins of the articular cartilages. The proper substance of the membrane is homogeneous, and characterized by an abundance of oval nuclei with little or no protoplasm round them, and

broader than those of the capillaries and the subjacent tissues. Near the articular surfaces an apparent continuity can be seen between cartilage-corpuscles and a stratum of scattered corpuscles on the surface of the membrane, presenting long and dividing branches, as also continuity with the oval nuclei mentioned. In many joints there are portions of the synovial membrane, of variable extent, more spongy and vascular than the rest, elevated into folds and pads by subjacent adipose tissue, and filling up gaps and recesses. These were described by Havers as *glandular mucilaginosae*, and are commonly spoken of as *Haversian glands*. Especially in places where the synovial membrane is thrown into projecting or receding folds, there occur thread-like and clavate projections or *villi*, both simple and branched, just visible to the naked eye, and sometimes containing encysted corpuscles, important as the source of loose cartilages well known to surgeons.

FIG. 34.—SYNOVIAL MEMBRANE. A, Synovial villi projecting from free edge of semilunar plate of the knee joint. One of them presents such a cluster of corpuscles, in a clavate extremity, as sometimes is inclosed in chondriniferous matrix and becomes the commencement of a loose cartilage, demanding removal. B, Silver preparation of synovial membrane close to the head of a metacarpal bone, showing flattened corpuscles sending out long branching processes and in series with cartilage-corpuscles, as well as with the oval nuclei represented in the upper border of the sketch.

Fibro-plates, usually described under the head of *fibro-cartilages,* occur in certain of the complete joints, and are tough, generally biconcave structures intervening between the opposed articular cartilages, intruding free surfaces between them, and attached peripherally to the fibrous surroundings. They may form imperforate *discs*, separating the cartilages completely, and thus lie between two distinct synovial cavities, as in the temporo-maxillary articulation; or may have the shape of a *meniscus*, only partially separating them, as in the knee joint; or they may be variable, sometimes perforated, sometimes not, as in the sterno-clavicular articulation. They consist of closely felted white fibrous tissue with no separable synovial membrane, but with oval nuclei discernible towards their surfaces, and with fringes of synovial villi at their edges and in their vicinity.

The development of complete joints is noteworthy in connection with the relation which incomplete joints bear to them. At an early period many parts of the skeleton are more massed together than afterwards, being as yet undifferentiated. Thus the bones of each limb form one continuous cartilage, and thus also each cartilaginous vertebra is continuous at each side with rib and sternum. The articulations which

subsequently divide these blocks by means of complete joints appear first, in each case, in the form of a fibrous line breaking the continuity of the cartilage; a cavity afterwards appears walled completely by synovial membrane; and at a later period the membrane disappears from the faces of the opposed cartilages. Certain joints, however, are placed between parts not originally continuous, but brought into contact by growth. This is the case with the joint between the head of a rib and the vertebra above it, the sterno-clavicular articulation and that between the sacrum and ilium. But probably in all instances there is fibrous continuity before formation of the synovial cavity.

Incomplete joints of two kinds are described—movable and immovable.

Immovable joints do not differ in any essential particular from the temporary separation of the diaphysis and epiphysis of one bone. Thus, we have seen that the sutures between bones of the skull remain open in connection with the growth of the bones; and if the separation, in early life, of the occipital from the sphenoid is to be considered as an articulation, there is no reason why the separation of the great wings of the sphenoid from the body of that bone should not be regarded in the same light. It would, however, be inconvenient to regard the whole cranium with the exception of the lower jaw as a single bone, or to distinguish as separate bones all its centres of ossification; and therefore the more permanently distinct masses justly receive separate names, though it is perfectly understood that several of the parts so recognized are united by osseous union long before adult life is reached, and that all may become united in the course of advancing years. The lines of contact of the bones of the skull are called *sutures*, and are distinguished as *serrated* when the edges are jagged and locked together, *scaly* or *squamous* when one edge overlaps another, and *harmonia* where there is mere apposition.

Incomplete joints of the *proper* or *movable description* have fibrous tissue attached over the whole extent of the exposed surfaces of bone; and this fibrous tissue is always mixed with cartilage at its attachment, constituting one of the varieties of so-called fibro-cartilage. At the symphysis pubis, this cartilage sometimes becomes calcified as age advances. A synovial pouch is also sometimes developed in the ligamentous junction of the bones at that joint; but the articulation remains incomplete in respect that the membranous wall of the cavity is continuous, and there are no opposed surfaces of bare cartilage.

Intervertebral discs. The most remarkable of the incomplete joints are the intervertebral discs uniting the bodies of the vertebrae. These are to a certain extent complicated in their development by their connection with the notochord (p. 91); but each presents from its surface inwards a gradual transition from laminae of white fibrous tissue to the pulpy mass which occupies its centre. This pulp, as pointed out by Luschka, exhibits grapelike processes about an eighth of an inch in average size, with free surfaces and arranged in clusters, filling up the cavity into which they

project, and comparable with the villi of a synovial membrane. The pulp of the intervertebral discs exhibits in a stroma of connective tissue incapsuled corpuscles, single, and in groups, identical with cartilage-corpuscles, and is therefore one of the structures long described under the name of fibro-cartilage, but it is a structure *sui generis*, with affinities to synovial villi as close as to cartilage. It presents sometimes corpuscles with laminated capsules.

FIG. 35.—LUMBAR INTERVERTEBRAL DISC, horizontal section, showing the grapelike processes of the pulp and the laminae of fibres around it.

Movements of joints. In speaking of movements of joints it is necessary to distinguish between movements of the articular surfaces and the direction of the movement given to the part of the body to which the moving articular surface belongs.

The movements of articular surfaces are of two kinds, gliding and rolling; and these are very generally combined. *Gliding* is the shifting movement of one surface on another with friction. *Rolling* is the movement by means of which successive portions of surfaces are removed from contact, while others in front of them come into contact, without friction, as the parts of a carriage-wheel successively touch the ground. For a purely gliding movement surfaces must be perfectly conformable and of uniform curve; but in many instances opposed articular surfaces are not conformable, they cannot be brought into perfect contact throughout, and they are often facetted. In these circumstances, there is an element of rolling or coaptation in the movement; the opposed surfaces approaching in certain parts, and receding in others, so as to leave a slight gap into which Haversian glands are pressed.

The *directions of movement* of which a joint may be the centre are of three principal kinds—angular movement, rotation, and circumduction.

Angular or hinge movement is movement in one plane, and may consist of bending, straightening, and bending in the reverse direction, technically termed *flexion*, *extension* and *over-extension;* or of movement toward and away from the middle line, *adduction* and *abduction.*

Rotation is revolution round the long axis of the part moved, and *circumduction* is conical movement, in which the distal end of the part set in motion circumscribes an area. It is further to be noticed that there are joints allowing of but slight motion, which may be useful, not on account of the unimportant difference of position of parts which is allowed, but by giving elasticity, through causing weight to be borne by tense ligaments instead of being conducted through solid bone. This is the principal use of the carpo-metacarpal and tarso-metatarsal articulations.

Nomenclature. The following terms, long applied to joints, though some of them falling into deserved desuetude, require explanation. *Diarthrosis* means a complete joint, *amphiarthrosis* a movable incomplete joint, and *synarthrosis* an

immovable joint. Among the varieties of complete joints have been recognized *ginglymus*, or hinge-joint; *enarthrosis*, the ball and socket joint; *diarthrosis trochoides*, or pivot joint, and *arthrodia*, permitting only slight movement. *Symphysis* is a word formerly used as equivalent to amphiarthrosis, but survives as a term applied to two mesial structures — the symphysis pubis, which is an amphiarthrosis or incomplete joint of the movable sort, and the symphysis of the lower jaw, which is an immovable union of right and left parts, and undergoes ossification in early life. *Synchondrosis*, signifying union by cartilaginous substance, is a term applicable to the union between occipital and sphenoid, and equally so to the union between principal centres of ossification and their epiphyses, but has been principally applied to the sacro-iliac articulation, which is not really a synchondrosis at all, but a complete joint. *Schindylesis* has been used as a term to indicate the reception of an edge of bone into a cleft, the articulation of the vomer with the vaginal processes of the sphenoid being the example given; and *gomphosis* as a word suitable to indicate the fitting of the teeth into their sockets; but the vomer articulates edge to edge with the vaginal processes, and the teeth, though impacted in the jaws, are no part of the skeleton.

MUSCLE.

Muscle is a texture consisting of fibres whose special characteristic is the property of contractility. By contractility is understood the tendency of parts to approach one another temporarily under the influence of stimulation; and the exercise of this tendency, as exhibited in muscle, is always accompanied by metabolic change; that is to say, breaking down of organic compounds by oxidation, or, as it may be termed, consumption of fuel. Contractility probably exists in connection with the protoplasm of all young living corpuscles; and in connection with amoeboid movements it is exhibited in an unlimited variety of directions. But in muscular fibre the contractility, while greatly increased in amount, is confined to one direction, namely, the length of the fibre. The shortening of the fibre involves a separation of particles laterally, there being no total diminution of bulk. The return of the fibre to its original shape is effected, not by contractility, but by elasticity, which involves no chemical change.

Muscular fibre exhibits two great varieties distinguished by microscopic characters as *striped* and *unstriped*, and physiologically as *voluntary* and *involuntary*. The terms voluntary and involuntary are, however, not without objection; for in no voluntary movement do we will the contraction of individual muscles; it is the movement to be effected which is voluntary, while we remain ignorant of the muscles by which the movement is accomplished. Also, it is notable that while the contraction and dilatation of the pupil have probably the same relation to volition in birds as in mammals, in birds the muscular fibres of the iris are striped, and in mammals they are unstriped. Lastly, the pharynx and upper parts of the oesophagus, though they are removed from the control of the will, have typical striped fibres, and the heart has striped fibres

with peculiarities special to it. But it may be noted that the contractions of the heart and the movements of the bird's iris are more sudden than those of unstriped muscular fibre, and that it is in this respect that striped muscular fibre differs distinctively in function from unstriped; for it both begins to contract more immediately after stimulation and completes its contraction more quickly.

Unstriped muscular fibres are generally disposed in continuous sheets, as when they surround hollow viscera, or in separate fasciculi, as in the erectors of the hair-follicles. Striped muscular fibres are arranged in fasciculi or bundles, which are occasionally disposed in sheets, as in the upper part of the oesophagus, and in subcutaneous muscles such as the platysma myoides in man, or the panniculus carnosus of animals; but are generally collected in more distinctly individualized muscles attached to bone, and either applied directly to the periosteum or fastened by the intervention of tendon.

A muscle is, therefore, an organ into which other structures enter besides muscular fibres. Not only has it got one or more arteries and veins, a branch of nerve, and, in most instances, some tendinous arrangement; but, in addition, it has its special investment or *perimysium* of connective tissue, and has its fibres arranged in fasciculi bound together by more delicate connective tissue, the *endomysium* of authors.

The actions of muscles are modified by the manner in which their muscular fasciculi are disposed, the strength of their contraction depending on the number of fasciculi which act together, and the extent of this contraction depending on the continuous length over which the fasciculi extend, no matter though broken by tendinous intersections. It follows that if two muscles have the same length and bulk, but one has its fibres running lengthwise, while the other has short fibres arranged obliquely between tendons of origin and insertion, so as each to repeat the action of the others, the first muscle will be capable of contracting to a great extent but with little force, while the second will maintain its contraction with great strength, but will be incapable of shortening itself to the same extent. Thus, for example, the semitendinosus muscle has long fibres, while the semimembranosus, lying beside it, has its fibres much shorter and more numerous; both are placed on the stretch when the trunk is bent down and the knees kept straight, and the semimembranosus will be the more powerful in helping to raise the trunk; but when the origin and insertion of both muscles are approached by throwing back the thigh and bending the knee preliminary to delivering a kick forwards, plainly the long-fibred muscle, the semitendinosus, can alone be effective, the extent of contraction possible for the semimembranosus being unequal to shorten it to the extent that the semitendinosus can be shortened. Chemically, both striped and unstriped muscular fibres consist in greater part of muscle-fibrin, which during life is in the form called *myosin*, and after death is speedily changed in ordinary

circumstances to another variety named *syntonin*, soluble in dilute muriatic acid.

Microscopic structure. Smooth or unstriped muscle consists of separate nucleated corpuscles, usually termed fibre-cells. These are flat and elongated, with pointed extremities more or less drawn out. Their substance

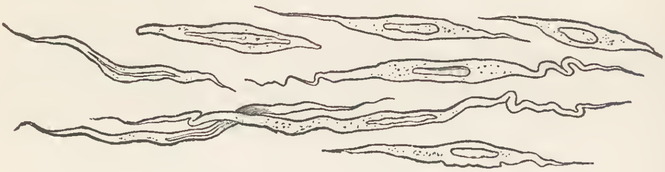


FIG. 36. — UNSTRIPED MUSCULAR FIBRE-CELLS from various situations.

is nearly structureless, but may exhibit a slight indication of longitudinal lines. They tear easily across, and, when isolated, tend to fall into zigzag folds, with parts lying flat between. They have no cell-wall. The nucleus is elongated, often rod-shaped. The fibre-cells are of very different sizes in different localities, reaching $\frac{1}{100}$th inch in length in the stomach and intestines, and a greater development in the pregnant uterus, while in the iris and other places they are very much smaller. Nor are they always of the same shape; occasionally they show bifidity, and they vary in proportional breadth, those of the longitudinal layer of the intestine being narrower than the somewhat shorter fibres of the circular layer. In situations where they are well developed they tend to adhere in longitudinal bundles bound together with cement. In the stomach and intestines they are supported by a network of fine elastic fibres.

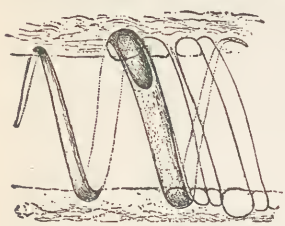


FIG. 37. — UNSTRIPED MUSCULAR FIBRE-CELL, coiled $2\frac{1}{2}$ times round in the wall of a minute artery, and showing an elongated oval nucleus. (Lister.)

The nerves of smooth muscle form a network from which branches were traced by Klebs, Frankenhausen and J. Arnold, more than twenty-five years ago, to the nucleus of the fibre-cell; but others have failed to verify the observation.

Striped or striated muscle consists of cylindrical or polygonal fibres of complex constitution and indefinite length, which present for consideration contractile substance, nuclei, and a sheath or *sarcolemma*. The best developed striped fibres are those of the limbs and trunk, and may reach a breadth of $\frac{1}{400}$th inch. Others, as in the face, may be narrower than $\frac{1}{2000}$th inch. In the tongue there are vertically placed fibres branching to the surface with ramifications of much greater tenuity. It has been alleged that the length of a fibre generally does not exceed $1\frac{1}{2}$ inches, and that rounded ends of fibres may be seen in muscular fasciculi; but such statements are to be received with caution. The undoubted terminations of muscular fibre in tendon are irregular rather than rounded,

and although similar appearances are frequent in the course of muscular bundles, it seems probable that they are the result of accident in manipulation.

The transverse striae from which the fibres are named extend, when undisturbed, right across each fibre; they are closely set and at regular intervals. The appearance is due to a doubly refracting and dense stripe alternating with a singly refracting and less dense substance, in the middle of which latter is a faint line, formerly called a membrane by Krause, and sometimes presenting the appearance of a single or double row of dots. The less dense stripes may be rendered brittle by reagents which fail to harden the whole substance, such as weak alcohol, and the fibre then breaks up transversely so as to separate more or less completely the *discs* or *sarcomeres*, as they are called, although in point of fact it is only the peripheral parts of the dense stripes that are seen separated. But when pressure is applied after the whole substance has been hardened, the fibre exhibits longitudinal striation, and may be broken up artificially into a number of *fibrillae*, consisting of a linear series of alternating denser and less dense parts corresponding with the striae of the fibre. The less dense parts are still traversed in the fibrillae, as in the undivided fibre, by a line first noted in the fibrillae by Dobie (1849). So much as lies between two such lines is a *sarcous element* of Bowman. The fibrilla can be still further broken up into threads of such tenuity that the dense parts of the striae appear as longitudinal lines, while the intervening spaces are interrupted by a single or double dot. These ultimate threads or columns may be seen in transverse sections of muscle as minute areae, and are described as separated by a network of *sarcoplasma* or *sarcoglia* interpenetrating and surrounding the striped mass or *rhabdia*.

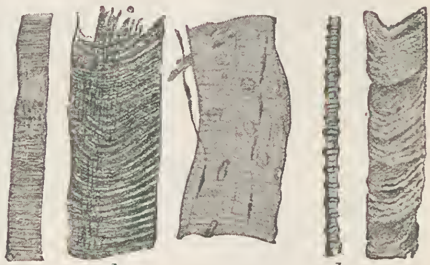


FIG. 38. — STRIPED MUSCULAR FIBRE. *a*, Fibre from face, bruised at one part so as to divide the contractile substance without injuring the sarcolemma; *b*, from pectoralis major, showing striae with fine line in the light spaces, and also tendency to break into fibrillae; *c*, a similar fibre stained, treated with muriatic acid, and washed with carbolic acid, the proper nuclei in the interior, broadly oval nuclei in the sarcolemma, two nucleated threads, and at the upper part a portion of a capillary vessel with its nuclei; *d*, a fibrilla under a higher power, showing Dobie's lines (dry preparation); *e*, fibre with marked inclination to break into discs.

The *sarcolemma* or *myolemma* is a delicate structureless membrane resembling elastic tissue in not being acted on by acetic acid, but passing insensibly at the extremities of the fibres into the substance of the tendon or other white fibrous tissue of attachment. It is absent from the muscles of the heart and the branching fibres of the tongue.

The nuclei of striped fibre lie underneath the sarcolemma in more than one row, and are of an oval form, with the long diameter about twice as long as the short, but other much longer nuclei exist in abundance adhering

closely to the surface of the sarcolemma. These are sometimes figured with granules beyond their extremities, but I find that they are united in linear series by threads which can be separated by carbolic acid from the surface of the sarcolemma. They differ widely in appearance from the capillary vessels.

Nerves. Striped muscle is supplied with medullary nerve-fibres which after branching come into close contact with them, then suddenly lose their medullary sheath and spread into branches likened to antlers. These with large nuclei between them and a certain amount of sarcoplasma are described as being beneath the sarcolemma, and constituting what are called the motorial end-plates (Kühne), and are confined to one part of the fibre. Nevertheless, the nucleated threads just described are, in my opinion, nerve-fibres continued from the extremities of the motorial end-plates and are never absent.

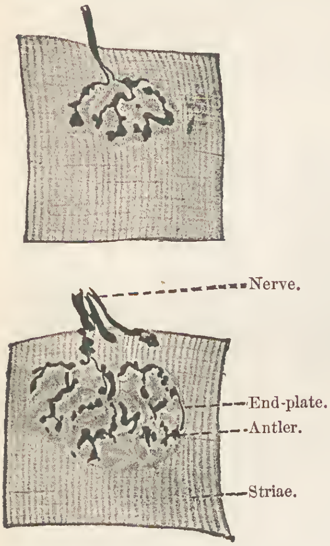


FIG. 39.—MOTORIAL END-PLATES of guinea-pig. (Böhm and v. Davidoff.)

An additional nervous terminal organ, the *organ of Golgi,* is found in many instances in the muscular extremities of tendons. It presents the form of a spindle-shaped swelling with a sheath involving several tendinous bundles and supplied with medullated nerve-fibres which divide and, losing their medullary sheaths, penetrate the inclosed tendinous substance, forming extensive networks and free terminations.

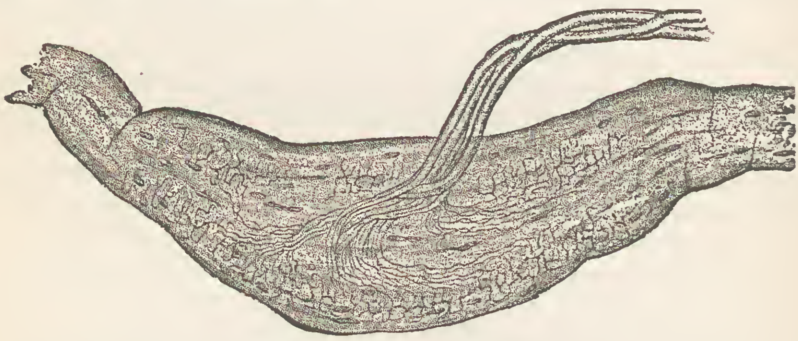


FIG. 40.—ORGAN OF GOLGI of rabbit, treated with very weak acetic acid. Three medullated nerve-fibres enter it and branch up. (Kölliker.)

The muscular fibres of the heart, though distinctly presenting striation in all its details, are sufficiently peculiar to require separate description. They are destitute of sarcolemma, and instead of forming distinct columns or

fibres of uniform breadth, are netted, each fibre giving and receiving divisions of smaller breadth which unite them with other fibres. They also present transverse marks, like partitions, dividing them into short lengths, in each of which may be seen a nucleus embedded in the contractile

Fig. 41. — *A*, Muscular fibres of heart; *B*, branched muscular fibre from tongue.

substance. On account of the transverse partitions the cardiac fibres are generally said to consist of chains of corpuscles with one nucleus each, but the component fibrillae are continuous through the partitions, and the partitions in many preparations are not seen. They appear to me to be separable by means of carbolic acid, and I regard them as interrupted portions of sheath, a ruptured sarcolemma.

Development of striped muscle. In the embryo, the corpuscles to be developed into muscle have the nucleus enlarged and then elongated, and become fusiform. Long fibres of uniform breadth are subsequently seen, with the nuclei at intervals in their interior. In opposition to the views of earlier observers, who considered that these were formed by coalescence of cells, it has more recently been taught that they are produced by elongation of the fusiform corpuscles and multiplication of their nuclei. But in the human subject both processes appear to occur; for the band between the nuclei is at first long and narrow, and afterwards when the fibres are of uniform breadth, division of nuclei may be seen taking place within them. Fibrillated substance appears first always at the periphery of the fibres, sometimes at one side; and transverse striation of the fibrillae can be detected from the first in them. The appearance of a sarcolemma also sets in very early. The fibres of the young embryo are

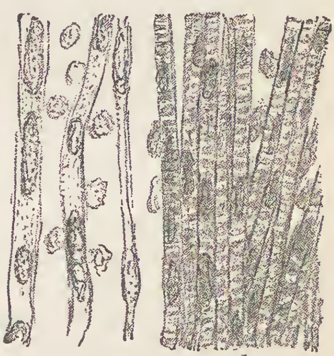


Fig. 42. — Striped Fibres in Process of Development. *a*, *b*, *c*, From human embryo 1½ inch long; *d*, from foetus of 5th month.

at first not a tenth of the breadth attained in the adult; but by the time of birth they have become much broader than they were.

Regeneration. There seems good reason to doubt the existence of any power of reproduction in either striped or unstriped muscular fibre. After parturition, the unstriped fibres of the uterus undergo fatty degeneration; and in pregnancy new fibres can be seen in process of formation from the unwalled corpuscles in the connective tissue between the bundles. As a consequence of typhoid fever, striped muscular fibre may undergo both fatty and colloid degeneration, the striation disappearing and being replaced in the one case by granules, in the other by masses of waxy-looking substance filling the sarcolemma, while new fibres are seen passing through the stage of spindle-shaped corpuscles (Zenker).

NERVOUS ELEMENTS.

While irritability would appear to be a universal property of the living elements of living bodies, it is the special office of the nervous system to bring the different parts of the body into relation one with another by conveying, through *afferent nerves*, irritation from different parts to nervous centres, and distributing from nervous centres stimulation, through *efferent nerves*, to tissues of different kinds, such as muscles and secreting glands. Structurally the two sets of nerve-fibres are indistinguishable, and even the functional distinction cannot be demonstrated in many visceral nerves. Nervous centres contain, in addition to nerve-fibres, nerve-corpuscles; and these two elements, together with supporting substance, constitute the nervous system. Nerves form the communications both of one nervous centre with another, and of the different nervous centres with the organs which they supply. In the latter case they are called *peripheral nerves* or *nerves of distribution*, and terminate in different modes, which will be described with the microscopy of the different organs.

The special elements of the nervous system, namely, nerve-fibres and nerve-corpuscles, are continuous one with the other; and every nerve-corpuscle is in itself a centre or, in some sense, a modifier of nervous action. Any collection of nerve-corpuscles, together with the nerve-fibres in connection with them, constitutes a *ganglion*. The simpler ganglia are distinct from one another, as in the sympathetic system, the branches of which are distributed in great part to the viscera; but the brain and spinal cord together form one great and complex organ, the cerebro-spinal axis, originating as a continuous axial structure, although portions of the brain containing nerve-corpuscles, and more or less separable from adjacent portions, are sometimes spoken of as cerebral ganglia.

Supporting substance. In the cerebro-spinal axis, in which enormous numbers of nerve-fibres and nerve-corpuscles are closely aggregated, this is of a delicate and modified description, giving a soft and distinctive

character to the texture, which is spoken of as *nervous substance,* and is broadly divisible into *white* substance and *grey* or *cineritious,* the grey alone containing nerve-corpuscles, and that not in every part. The white matter owes its whiteness to the abundance of nerve-fibres furnished with medullary sheaths described below. The grey matter lacks that source of whiteness, and has a much richer supply of capillary bloodvessels, while the nerve-corpuscles embedded in it have also a certain variable amount of pigment. The supporting substance is termed the *neuroglia* (or *glia*), but where it lines the walls of spaces it is sometimes, together with the epithelium, called *ependyma.* The glue-like material, of which it apparently consists, has been resolved by later research partly into interlacements of fine nerve-fibres which are not truly neuroglia, and partly into nucleated corpuscles with shaggy masses of long delicate threads extending far out from them, specially numerous around medullated nerve-fibres. These corpuscles, as will be pointed out in treating of the development of the spinal cord, are derived, like the nervous elements, from the primitive epiblastic cerebro-spinal axis; and from the same source there radiate branching threads continuous with the epithelial cells of the central canal; but it would be hazardous to maintain the absence of other supportive substance, seeing that we must suppose that the bloodvessels are developed in the ordinary way from mesenchyma.

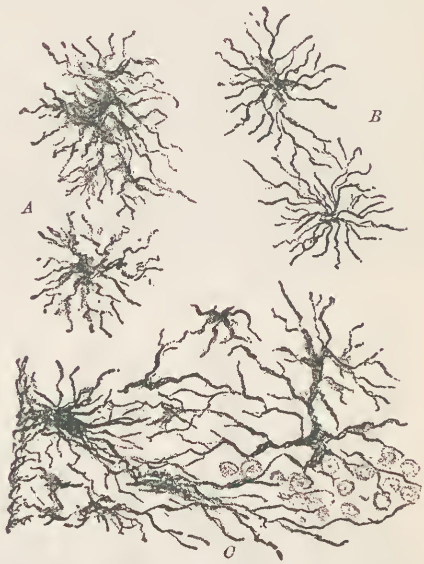


Fig. 43.—Neuroglia Corpuscles. *A*, From cerebral convolutions; *B*, from cerebellum; *C*, from peripheral part of white columns of spinal cord, with some medullated nerves in transverse section faintly seen. Prepared by John Morton, M.B.

The whole cerebro-spinal axis is surrounded by envelopes, and it is especially in the passage through the outermost of these, the *dura mater,* that the nerves have added to them the firm connective tissues to which they owe their tenacity throughout their distribution, a tenacity so great that they may be pulled without injury to their microscopic structure.

In their distribution the cerebro-spinal nerves are arranged in bundles or *funiculi,* and covered by investments of firm connective tissue, which have received names not always applied in the same way by different writers. The most characteristic investment, however, is that immediately surrounding the funiculi, the *perineurium,* a firm and distinct membrane with oval nuclei, known also as the *sheath of Henle.* External and internal

to the perineurium are lymphatic channels lined with endothelium. The delicate connective tissue within the perineurium is sometimes called *endoneurium*, and the denser sheath of white and elastic fibres binding the funiculi into larger bundles is termed *epineurium*.

Nerve-fibres are distinct threads, originating at one extremity from a nerve-corpuscle, and take their course without junction with any other, and without branching save within nerve-centres or at their peripheral extremities; but bifurcations abound within the cerebro-spinal axis, and when nerve-fibres reach the immediate neighbourhood of their peripheral termination they habitually branch. In the best developed nerve-fibres three distinct structures are found — the axis-cylinder, the primitive sheath, and the medullary substance between, from the presence of which they are called *medullated fibres*.

The *axis-cylinder* may be termed the essential part. If a perfectly fresh portion of a spinal nerve be examined, the majority of its fibres will be seen as clear structures of a breadth of as much as $\frac{1}{1500}$th inch, refracting the light, and bounded on each side by a double contour; but if by manipulation they be torn, the semi-fluid medullary substance will issue from them and bring into view both the sheath which contains it and a solid thread in the middle. This last is the axis-cylinder, and is of firm albuminoid substance deeply stainable with carmine. An appearance of fine longitudinal fibrillation may be detected in it.

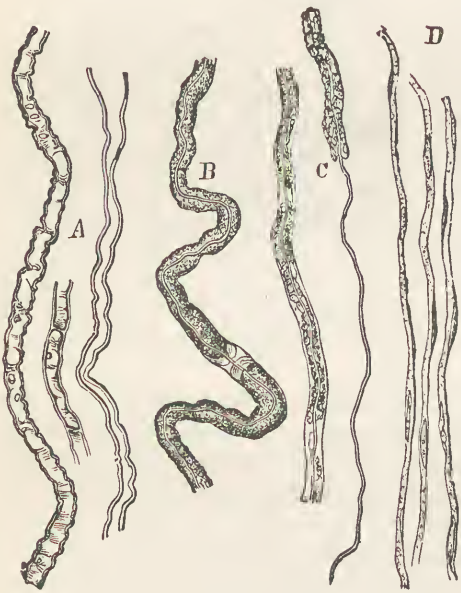


Fig. 44.— Nerve-Fibres. *A*, Medullated fibres of different sizes, fresh, from frog's leg; *B*, fibre from frog, treated with absolute alcohol; *C*, two medullated fibres, human — in the lower part of one, the axis-cylinder and primitive sheath are shown by removal of the medullary substance, and in the other, the axis-cylinder projects free from the primitive sheath and medullary substance; *D*, non-medullated (Remak's) nerve-fibres from sympathetic chain, human. (Toldt.)

The *primitive sheath*, *sheath of Schwann*, or *neurilemma*, is a delicate membrane which, like the sarcolemma of muscle, resists the action of acetic acid. It presents at intervals elongated nuclei which rather dip into the subjacent medullary substance than project on the surface; but when the medullary substance disappears, the axis-cylinder may continue invested with primitive sheath, or at least the nuclei may be continued on the axis-cylinder and project from it, or

even be separable. The nuclei are not found on nerves within the brain or spinal cord.[1]

The *medullary substance*, otherwise called *white substance of Schwann*, though homogeneous and clear in the fresh state, escaping freely from cut extremities and leaving the axis-cylinder and primitive sheath uninjured, becomes turbid and even reticulated, and, when acted on by reagents, has been found to exhibit in transverse section radiating dispositions of stainable substance embedded in it. When at once hardened in the thoroughly fresh state, it remains altogether unstained by carmine; but if less fresh it stains considerably. The main constituent of the medullary substance escapes from cut or injured fibres in homogeneous masses termed *myelin*, which yields protagon and cerebrin. It may be noted that it contains phosphorus and a very small proportion of nitrogen, is probably the source of the large amount of cholesterin yielded by decomposition of brain-substance both during life and after death, and is blackened by osmic acid. The medullary substance can be removed altogether so as to show the axis-cylinder in the middle of the primitive sheath.[2]

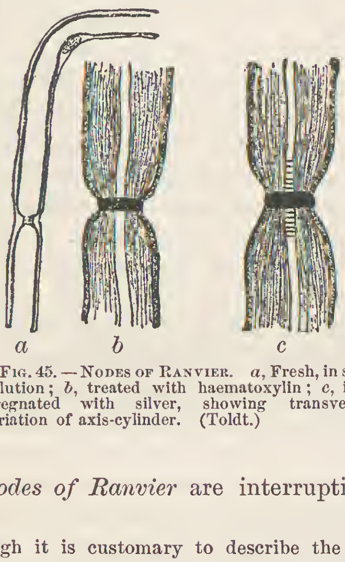


FIG. 45. — NODES OF RANVIER. *a*, Fresh, in salt solution; *b*, treated with haematoxylin; *c*, impregnated with silver, showing transverse striation of axis-cylinder. (Toldt.)

FIG. 46.—NOTCHES OF LANTERMANN. Osmic acid preparation. (Toldt.)

The *nodes of Ranvier* are interruptions of the medullary substance

[1] Although it is customary to describe the nuclei as belonging to the primitive sheath, they can in the case of the large medullated nerves be shown to be merely applied to it, and may even be separated from it, in the same way as the sarcolemma of muscle is distinct from the nuclei adherent to it.

[2] When the medullary substance escapes from the fresh nerve, it leaves adherent to axis-cylinder or to sheath none of the structures seen after changes have taken place. It seems to be simply an unstable chemical substance. It is worthy of note that nervous tissue is prone to decomposition proportionally to the amount of medullary substance contained in it. This circumstance, taken into account along with the instability of the medullary substance itself, makes it tempting to suggest that activity of the axis-cylinder may disturb the equilibrium of the medullary substance, and that this in turn may facilitate change in the axis-cylinder, and so promote nervous action.

caused by constriction of the lumen of the primitive sheath, and have the appearance of a transverse septum projecting inwards from it. They are sometimes described as occurring one between every pair of successive nuclei, but the nuclei are more frequent than the nodes have ever been figured. Oblique notches, *notches of Lantermann*, are often met with dividing the medullary substance into *cones*, different series of them facing one another; but they result from the effect of reagents and manipulation.

Fig. 47.—Unipolar Nerve-Corpuscles, from jugular ganglion of vagus nerves of dog, showing the single pole dividing into a large fibre, *p*, and a small fibre, *c*. The abundantly nucleated sheath is also shown, which invests the corpuscles of the ganglia of nerve-roots and of the sympathetic chain. (Kölliker, after Retzius.)

Of *non-medullated fibres* more than one variety ought to be recognized. Threads already alluded to, more or less broad, with elongated oval nuclei pressing in from the sides, appear to be properly described as axis-cylinders with the sheath prolonged on them, in so far as the nuclei are obviously the same as those on the sheath of medullated nerves. There are also naked axis-cylinders near the terminations of nerves, without any nuclei disposed on them. Lastly, there is to be distinguished from these a set of nerve-fibres abundant in the sympathetic system, present also in cerebro-spinal nerves, called sometimes *fibres of Remak*, and consisting of threads interrupted by elongated nuclei. The threads vary in breadth, being sometimes granular and as broad as the nuclei, but sometimes of the utmost tenuity and branching in their course.

On certain of the smaller nerve-fibres *ampullae* occur of two kinds. One kind, abundant on fine fibres in the cortex of the brain, is caused by irregular disposition of the medullary substance, and is probably always an appearance resulting from manipulation. The other consists of regular dilatations of an axis-cylinder, as in the neuro-fibrous layer of the retina, and the artificial origin of this kind of ampulla is more questionable. The milky white of the cerebro-spinal nerves arises from the large amount of medullary substance on a number of the fibres, the same cause as gives the whiteness to the white brain-substance. The less brilliant tint of the sympathetic nerves arises from the larger number of non-medullated or poorly medullated nerve-fibres.

Nerve-corpuscles are more frequently termed nerve-cells, but have no proper cell-wall. They vary in diameter from as much as $\frac{1}{200}$th of an

inch to a very minute size. They always present a granular appearance, and very generally contain a heap of yellow granules, also in some instances dark brown pigment. They have each a large nucleus, round and clear, containing one or two distinct nucleoli capable of being stained very deeply with carmine.[1] But perhaps the most remarkable character of nerve-corpuscles is the possession of one or more poles or branches. Corpuscles apparently apolar are often met with, but there is reason to believe that these are merely corpuscles which have had their poles torn closely off.

Fig. 48. — Bipolar Nerve-Corpuscles, from a sacral ganglion of a human embryo at the end of the second month. (Kölliker.)

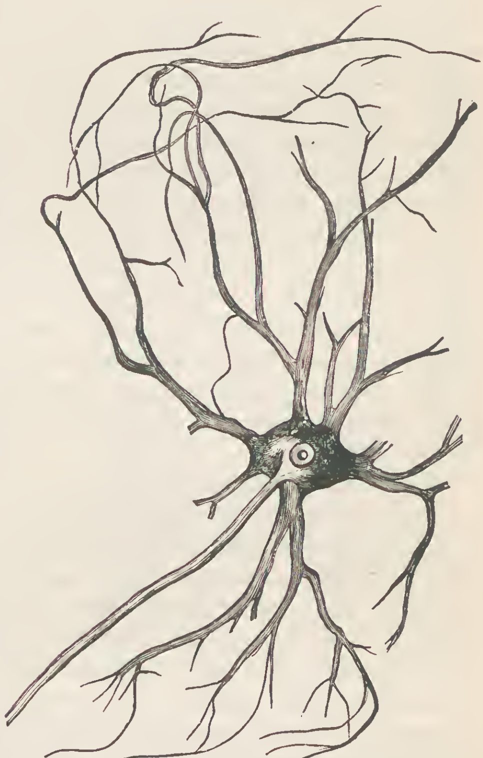


Fig. 49. — Multipolar Nerve-Corpuscle, from anterior cornu of spinal cord of ox; *a*, axis-cylinder process. (After Deiters.)

Corpuscles apparently unipolar occur in the invertebrata, with the pole continued into a single nerve-fibre; but the only known unipolar nerve-corpuscles in the mammal, those of the ganglia of the nerve-roots, are at an early stage of development bipolar, and subsequently draw their

[1] Nerve-corpuscles have recently been shown to exhibit differences of constitution and appearance, according as they have been at rest or in activity; activity being accompanied by increased size of cell, nuclei and nucleoli; rest by chromatic material in the cell, and fatigue by shrivelling of the whole structure and diffuse chromatic material in the nucleus (see Gustav Mann, *Journal Anat. and Phys.*, October, 1894).

bulk back from the poles so as to give them a common origin, through which currents of nervous action must pass in both directions. Also, bipolar corpuscles were described thirty years ago by Beale and Julius Arnold independently occurring in the sympathetic of the frog, in general appearance unipolar, but having one pole originating superficially and wound round another of deep origin, afterwards to separate from it and take an opposite direction.

In numbers of multipolar nerve-corpuscles the poles are well made out to be of two sorts — one remaining as a single stem, the axis-cylinder of a nerve, while the others break up repeatedly into smaller branches which end in fine extremities. Thus, in the multipolar corpuscles of the anterior cornua of the spinal cord, all the poles branch, save one, which is continuous with an emerging fibre of an anterior nerve-root, and is distinguished as the *axis-cylinder pole* or *pole of Deiters*. The arrangement is not universal, for the two original poles of the corpuscles of the spinal ganglia are certainly both axis-cylinders; but it is important.

The branching poles are called *protoplasmic*, as originating from the superficial part of the corpuscle, while the axis-cylinder has been supposed to have a deeper origin. The axis-cylinder, though remaining a continuous stem, or only once bifurcating, may give off numerous fine lateral branches known as *collaterals*, extending considerable distances within nervous substance; and both the main axis-cylinders and the collaterals terminate in *arborizations* or ramifications within a microscopic space.

Such details and much of the recent advances in knowledge of the nervous system are due to the methods of metallic staining invented by Golgi, principally those in which chromate of silver is deposited. From such observations Ramón y Cajal has arrived at the following generalizations: — "Nerve-corpuscles are independent unities, and never in continuity either by their protoplasmic branches or by their nervous expansions the axis-cylinders. Every axis-cylinder ends in arborizations, varicose and flexuose, after the fashion of the nervous ramifications of the motor plate in muscles. These arborizations apply themselves either to the bodies or the protoplasmic expansions of the nerve-corpuscles, establishing connections by contiguity or contact, as efficacious as connections by continuity of substance would be, for the transmission of the currents." Some observers believe the function of the protoplasmic branches to be purely nutritious; but if Cajal's views are correct, both the protoplasmic poles and the axis-cylinder are paths of nervous activity. Also, though we continue to speak of *commissures*, meaning thereby nerve-fibres uniting similar centres, it is plain that if nerve-corpuscles are never united there can be no true commissure between corresponding corpuscles of opposite sides, and transverse commissures must resolve themselves into decussations; and, indeed, there is other evidence that they are so in the spinal cord, the pons Varolii and the corpus callosum.

It is in harmony with the doctrine of the independent unity of nerve-corpuscles, that when nerves are cut across in the living animal the ends separated from their centres of origin undergo granular degeneration. This is called Waller's law, and affords a valuable means of tracking the continuity of fibres in the cerebro-spinal axis, and of determining, according as the degeneration is *ascending* or *descending*, the direction in which nerve-corpuscles of origin are to be sought.

Both the spinal and the sympathetic ganglia differ from the brain and spinal cord in having, like the distributed nerves, abundance of white

FIG. 50.—MINUTE GANGLION FROM GALL-BLADDER OF DOG. *a*, Axis-cylinder process; *b*, protoplasmic processes, which form a plexus at the periphery of each ganglion; *c*, sympathetic cells. (Dogiel.) Methylene-blue preparation.

FIG. 51.—GANGLION FROM GALL-BLADDER OF DOG, with fine nerve-fibres ending in it. *a*, *a*, Non-medullated fibres; *b*, a medullated fibre. (Dogiel.)

FIG. 52.—MEDULLATED NERVE-FIBRES UNDERGOING DEGENERATION AND REGENERATION. *Dg*, Conditions of degeneration—the first fibre from the rabbit, the second and third from the frog; *Rg*, conditions of regeneration, from the rat. (Toldt, after Sigm. Mayer.)

fibrous tissue entering into their composition. In the larger ganglia, the primitive sheath of the nerve-fibre is continued round each nerve-corpuscle, and in connection with the sheath there is a layer of flattened nucleated corpuscles enveloping each. In all the separate sympathetic ganglia, as distinguished from isolated nerve-corpuscles in ultimate diffuse plexuses, the corpuscles are made out to be multipolar with one axis-cylinder process, which at its far extremity ends in an arborization.

Development and regeneration. While it is ascertained that the nerves and nerve-corpuscles of the brain, spinal cord and spinal ganglia, and even the earliest fibres to the muscles are derived from the medullary epiblast, the origin of the nerve-corpuscles of the sympathetic and of the plexuses of distribution, such as those within the cornea, heart, diaphragm, and intestines, is more problematical.

The medullary sheath, when present, is always a later formation, and within the brain and spinal cord different strands acquire it at different periods of development, a circumstance which has been made use of by Flechsig to distinguish different continuous tracts of fibres.

When a nerve is divided, the granular degeneration which sets in causes the axis-cylinder of the distal end to waste away, at the same time that the nuclei in connection with the primitive sheath become more numerous and prominent, but it is not certain that they assist in regeneration. The new axis-cylinders are formed in continuity with those on the proximal side of the lesion, and, according to Ranvier, two or three may come from the cut end of one, and force their way on in the track of the degenerated nerve.

EPITHELIUM.

The word *epithelium* is used to indicate a covering of nucleated cells or corpuscles on a free surface; and, with little exception, all free surfaces have an epithelium, either consisting of one layer of corpuscles, in which case it is *simple*, or of several layers, and then it is said to be *stratified.* The individual corpuscles may have cell-walls or may have none; they may vary in consistence from a delicate pulp, or a film of the utmost tenuity, to the densest horn; they are of numerous forms and functions; and they are, as a rule, united by a cement more easily soluble than themselves, to constitute a continuous texture.

Simple epithelia are named according to the characters of their corpuscles, *squamous, columnar, cubical, spheroidal, polygonal* and *ciliated.*

Stratified epithelia are named from the character of the superficial stratum of cells, according as these are squamous, cubical or ciliated. The cells of their deeper layers present a great variety of appearances, requiring separate descriptions in each locality.

Squamous epithelia exhibit corpuscles having the form of flat scales of considerable size, each with its nucleus. Many *simple squamous epithelia* are of extreme tenuity, and some became known for the first time when weak solutions of silver nitrate came into use. The silver has a special tendency to deposit on the cement between the scales, chloride being formed, which on exposure to light is decomposed, leaving the oxide, and brings the lines of contact into view, even when it is not deposited in their interior, so as to show their structure. To this order of epithelia belong the linings of the heart and bloodvessels, lymphatics, serous membranes and the

walls of spaces associated with the lymphatics in the connective tissues. They are usually now distinguished as *endothelia*, and, while other epithelial cells are either epiblastic, hypoblastic or genito-urinary in origin, endothelium is mesoblastic, and may be derived from corpuscles in the connective tissues. Hence the term *epitheloid cells* is sometimes used instead of endothelium.[1] Simple squamous epithelium is also found behind the

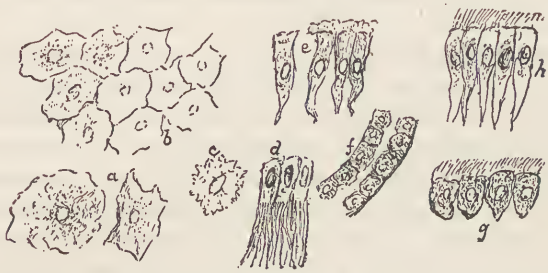


FIG. 53.—VARIETIES OF EPITHELIAL CELLS. *a*, Squamous cells from epithelium of inside of cheek; *b*, simple squamous lining or endothelium of serous membrane; *c*, spiny cell from the growing epidermis; *d*, digitate cells from deepest layer of epidermis of palm; *e*, columnar cells from intestine; *f*, cubical cell from tubule of kidney; *g*, ciliated spheroidal epithelium from choroid plexus; *h*, ciliated epithelium from trachea.

cornea, in the air-cells of the lungs, and in the loops of Henle and the Malpighian corpuscles of the kidneys. *Stratified squamous epithelium* is found constituting the epidermis all over the body, and likewise lines the mouth, lower part of the pharynx, and the oesophagus, down to the stomach; also the vagina, and, we may add, the urinary bladder, though its epithelium is sometimes called transitional.[2]

Columnar epithelia are those which have their cells vertically elongated. Plain columnar epithelium in no case presents more than one distinct layer, but the larger air-passages have stratified ciliated columnar epithelium.

Cubical epithelium is a convenient term to indicate epithelial cells which have the vertical and transverse diameters nearly equal. They are not cubes but short cylinders which present a square appearance in vertical section. The tubuli uriniferi have simple cubical epithelium, the ureter stratified cubical.

[1] Although the word *epithelium* was introduced by Ruysch to indicate the covering of the papillae of the lips, because he deemed the term *epidermis* inappropriate in that situation, and doubtless he had in view θηλή, a nipple, subsequent histologists appear, as microscopy advanced, to have adopted it as if coined directly from θάλλω, as it might have been, to signify a superficial bloom. Only in this way can the modern use of the word epithelium be justified. It is the derivation approved of by Allen Thomson (Quain's *Elements*, 7th ed.), and defends German anatomists from the strictures of Sharpey and Hyrtl on the etymology of *endothelium*.

[2] The term *transitional* ought to be allowed to drop. Introduced by Henle to indicate transition from spheroidal to columnar or scaly (Sharpey, in Quain, 5th ed., XCIX.), it has lately been used to signify transition from simple to stratified (Schäfer, in Quain, 9th and 10th eds.), and, thanks to the introduction of the word *cubical*, it is not required in its original sense.

Spheroidal epithelial cells are found in the ventricles of the brain; they bear cilia, and constitute a ciliated spheroidal epithelium. The term spheroidal is further applied to the secreting corpuscles occupying the lobules of a number of glands, such as the salivary; corpuscles whose shape is more aptly described as *polyhedral.* They are often called *glandular* epithelium, but their shape is not distinctive of glandular function, seeing that secreting corpuscles are often of a cubical or columnar form.

Ciliated epithelium presents on its free surface innumerable cilia or hair-like processes crowded together on the individual cells. These cilia during life are in constant motion, so rapid that individually they are invisible, though their presence is made apparent by the movement they give to the fluid in which they are lying. The cells on which they are placed have always a cell-wall, and the movement continues as long as the cell is kept alive in a suitable serum or weak saline solution. Small groups of cells scraped from a surface may be rotated rapidly by the motion of the cilia. If the movement be watched as it grows slower before stopping, it will be seen that the cilia bend over in one direction, straightening themselves with a feathery sweep, and move the fluid in the direction in which they bend. The movement is always in one direction, and is doubtless always towards the outlet of the passage lined, thus keeping it microscopically free from solid particles. The cilia have been made out to be connected with the protoplasm within the cells, but no structure has been demonstrated in them. It is ingeniously suggested by Schäfer that they may be hollow and moved by the projection of substance from within the cell. If the one side be supposed to be hollow and expansible while the other is resistant, the theory is compatible with the straight position of the cilia after death, and with the bent position being that of tension. In mammalia ciliated epithelium may be either simple or stratified, and is columnar, except in the four ventricles of the brain, where it is simple spheroidal, though in the central canal of the cord it is simple ciliated columnar. Ciliated epithelium is found throughout the respiratory tract, with certain exceptions, and in the Eustachian tubes and lachrymal passages; also in the epididymis, and in the uterus and Fallopian tubes.

Regarded functionally, epithelium of the squamous sort is generally protective, although the sebaceous glands seem to offer an exception to this rule; ciliated epithelium has likewise a mechanical function, keeping surfaces clean; polygonal, columnar and cubical epithelium are the forms most frequently devoted to secretion. Epithelial cells may also be associated with nervous functions. Thus, in the submaxillary gland, secreting corpuscles are continuous with efferent nerve-fibres, and in all the organs of special sense there are specialized epithelial elements continuous with afferent nerve-fibres.

GLANDS.

Secretion, generally speaking, consists in the extraction from the blood or the elaboration of special substances by epithelial corpuscles, and the pouring of them out on a free surface. No doubt the moisture found in serous and synovial sacs is not obviously influenced in quantity or quality by the endothelium; yet its varieties of character suggest that it is more than a transudation from the bloodvessels and textures around. As to the structures called ductless glands, while some of them have arresting and elaborating powers, they differ from secreting glands in that they do not pour their products out on a free surface. Absorption by epithelial corpuscles, such as is carried on by the columnar epithelium of the intestine, is similar to secretion, in respect that substance is attracted into the nucleated corpuscles and passed on by them; but it differs in the direction of the current, the current in absorption being directed from the surface inwards, and, in secretion, from the bloodvessels to the surface.

A surface which secretes is a *secreting surface*, but the free surface in connection with secretion is very generally extended by deep recesses; and these recesses, with the secreting epithelium within them, and the vessels, nerves and supporting texture about them, constitute *secreting glands*.

Glands are called simple or compound according as they consist of one or more recesses, and are called tubular or sacculated according to the shapes of the secreting parts. Simple straight tubules are exemplified in the tubular follicles of the intestine; the sweat-glands are mostly simple convoluted tubules, and compound tubular glands are exemplified by the testicle and kidney. The nearest approach to simple saccules is found in some of the sebaceous glands of the skin, but even these always show a certain tendency to lobation. Compound sacculated glands have the saccules forming little dilatations containing polygonal secreting corpuscles, which may be of such considerable size as nearly to fill them. These ultimate dilatations are termed *acini*, and the glands made up of them are said to be *acinated*, and from their arborescent arrangement are also called *racemose*. The salivary and buccal glands and the pancreas are racemose glands.

Only in short simple glands or follicles is the whole recess given to the preparation of the special secretion. The tubular passages which in other glands lead to the secreting parts are called the *ducts*, and in acinated glands they branch and become smaller, till they end in the ultimate secreting acini.

The wall of the gland or membrane on which the secreting corpuscles lie always presents a definite line on section, and is termed *membrana propria*. It may be strengthened in acinated glands by a layer of flattened corpuscles united edge to edge so as to form a more or less complete

investment, which has been likened to basketwork. This is sometimes spoken of as constituting the membrana propria. The word *basement membrane* is also used instead of membrana propria, but might with advantage be discarded. Between the secreting pouches there is generally a considerable development of retiform tissue.

FIG. 54.—LOBULES OF PAROTID GLAND of embryo lamb, five inches long, illustrating ducts and acini.

Secreting corpuscles are in some instances, as the columnar epithelium of the intestine, distinctly walled cells; but in others the presence of a cell-wall is exceedingly questionable, or may be even denied. Some, as those of the convoluted tubules of the kidney, have the protoplasm always turbid; others, as those of the straight tubules of the kidney, have it always clear. In other situations, as in the gastric follicles, the secreting cells vary distinctly in appearance, according to the condition of activity, becoming most deeply stainable when exhausted. In many parts mucigen is liable to collect in mass towards the free surface of the cell, driving the protoplasm and nucleus to the deep end; causing in the intestinal epithelium swollen and open cups called *goblet-cells,* and in salivary glands giving rise to the distinction of *mucous acini* from others termed by some authors *serous,* which have the protoplasm uniformly diffused, and the nuclei in the middle.

BLOODVESSELS.

The blood, though in the lower forms of animal life it circulates in contact with the tissues, is, in all vertebrate animals, contained everywhere within walled vessels which constitute a closed circulatory system. In only one organ is there a probable exception to this, namely, the spleen. The bloodvessels are of four kinds, viz., the heart, arteries, veins and capillaries. The arteries distribute the blood from the heart to the minute capillaries, which permit the flow of substance through their walls both to and from the tissues; and the veins bring the blood back to the heart. The heart is in the early embryo a simple tube, like the other orders of bloodvessels, but becomes developed into a distinct and complex structure which is the central organ of two distinct circulations, the pulmonary and the systemic. The pulmonary arteries carry impure blood from the left side of the heart to be aerated in the lungs, and the pulmonary veins bring it back purified to the left side of the heart, whence it is carried by the systemic arteries, viz., the aorta and branches, and, having been distributed throughout the body, is brought back by the systemic veins, viz., the superior and inferior vena cava, to the right side of the heart.

The Arteries have tough thick walls, the walls of the systemic arteries being considerably stronger than those of the pulmonary circulation. They elongate and expand when fluid is propelled into them, and recover their form by their elasticity. The larger arteries, when empty, are flattened by the pressure of their surroundings, but their walls are too thick to admit of their being in perfect contact; the smaller arteries contract circularly.

Arteries have got three coats, with different properties, each containing more than one kind of texture. If an artery be cut across, the greater part of the thickness of its walls presents a yellowish tint. This part is the *tunica media,* and the whiter and less dense coat outside it is the *tunica adventitia,* while internally, with the assistance of a lens or a low power of the microscope, a thin membrane can be distinguished, the *tunica intima.*

The *tunica adventitia* consists principally of dense areolar tissue, the felted bundles of which are seen with the naked eye crossing one another with every degree of obliquity. In its deeper part it likewise contains abundant yellow-elastic tissue so arranged as to be intermediate between perforated membrane and a lattice-work of fibres with longitudinal inclination. When an artery is ligatured, the tunica adventitia remains intact.

The *tunica media* consists of two elements — yellow-elastic tissue and unstriped muscle. The yellow-elastic tissue is less fibrous than in the

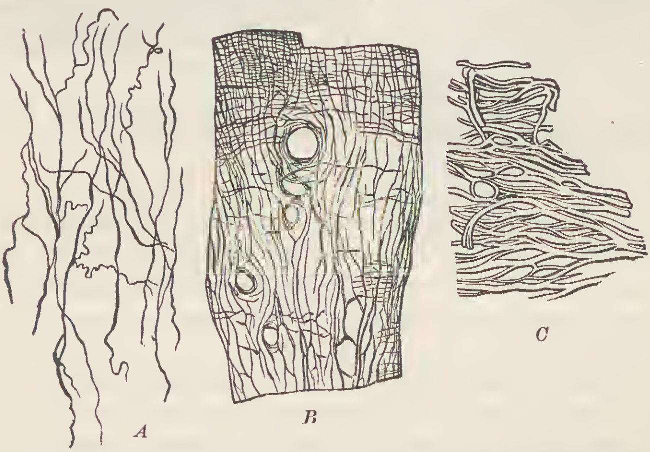


FIG. 55. — ELASTIC TISSUE FROM OUTER AND MIDDLE ARTERIAL COATS. *A*, Fine network from middle coat of radial artery; *B*, elastic lamina from middle coat of subclavian artery; *C*, coarse network from bounding layer between middle and outer coats of femoral artery. (Toldt.)

tunica adventitia, and presents delicate laminae, which intercommunicate so as to form a network inclosing the muscular fibres in its meshes. The muscular fibres form the principal bulk of the middle coat. They are circularly disposed. When an artery is ligatured the thread presses

asunder the muscular bundles and ruptures both the middle and internal coat; both coats are retracted by elasticity, while, in the living subject, the muscular fibres contract, diminishing the calibre of the vessel above the ligature, and exposing the ruptured edge to the blood so as to induce coagulation. Superficial to the circular muscular fibres there occur in some exceptional arteries scattered longitudinal fibres in the deep part of the tunica adventitia. This has been specially noticed in the splenic, mesenteric, renal, uterine and spermatic arteries, and those of the penis. Also, longitudinal fibres are noted by Bardeleben at the inner boundary of the tunica media in all the larger arteries.

The *tunica intima* is brittle, thin and transparent, and may be torn off in shreds. It consists of three layers, viz., (1) a layer of endothelium, the cells of which are mostly elongated in the direction of the vessel;

FIG. 56.—SECTION OF ARTERY, $\frac{1}{20}$ inch wide, showing the dense muscular tunica media, with tunica adventitia around it, and the clear crenated tunica intima within.

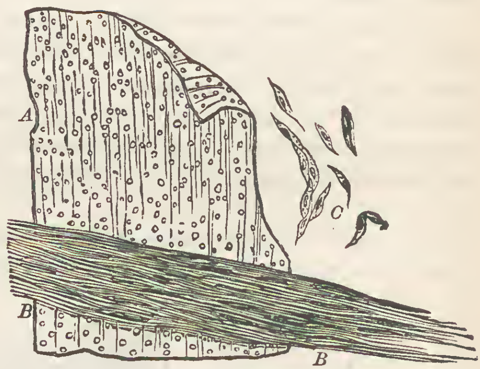


FIG. 57.—*A*, fenestrated membrane of tunica intima; *B*, muscular fibres of tunica media adherent to tunica intima; *C*, partially isolated endothelial cells. (Toldt.)

(2) a very delicate layer of branched corpuscles in homogeneous matrix, important to the pathologist as being the seat of the changes which lead to aneurism and calcification; (3) an elastic membrane marked with lines as of separate fibres, and frequently showing perforations, the *fenestrated membrane of Henle.*

Arteries, as a general rule, divide dichotomously and give off smaller branches in their course. The coeliac and the thyroid axis are examples of trunks terminating at once in three. In various animals an artery breaks up suddenly into a number of minute trunks which are afterwards gathered together again, and this is termed a *rete mirabile.* Such an arrangement is found at the base of the skull of the sheep, in various parts of the bodies of ant-eaters, in the legs of running birds, and in other animals; but the only thing of the sort in the human subject is on a minute scale and common to man and other animals, the glomeruli of the kidneys.

When two vessels unite, either to form a third vessel receiving its blood from both, or a communication in which the direction of the current may vary from time to time, they are said to *anastomose.* Arteries for the most part anastomose by means of small twigs only, as in the face and neck they do across the middle line, or as do the terminal twigs of branches given off at different levels in the limbs; but in the mesentery the main branches unite in arches from the convexities of which other branches arise to form arches in like manner; and at the base of the skull two large trunks, the vertebral arteries, unite to form one mesial vessel, the basilar. Arteries generally continue of precisely the same calibre as long as they give off no branch, but the spermatic artery increases in size. In most instances, when an artery divides, the sum of the sectional area of its divisions exceeds the area of the undivided trunk; and by the following out of this rule, the total arterial channel enlarges and the rate of flow of the blood diminishes from the heart, till the capillaries are reached; but an exception to the rule occurs at the division of the aorta into the two common iliac arteries.

In the smallest order of arteries, *arterioles,* those which lead into the capillaries, it is easy to see under the microscope, (1) the oval nuclei of the endothelial scales of the tunica intima elongated in the direction of the vessel, (2) the muscular fibres of the tunica media lying in a single layer, the individual fibres sometimes wrapped twice or more round the vessel (Fig. 37), their nuclei crossing it transversely, and (3) spindle-shaped nucleated corpuscles lying longitudinally and representing the tunica adventitia.

Fig. 58.—Arteriole and Venous Radicle. *a*, Artery; *b*, vein; *c*, arteriole passing into capillary. Corpuscles of outer coat spindle-shaped, muscular fibres transverse, nuclei of endothelium oval.

The larger arteries, as also the larger veins, have in their walls small vessels for the nourishment of their structure, which are termed *vasa vasorum.* Nerves also are found in plexuses in the walls of at least all bloodvessels in whose walls there are muscular fibres.

The capillaries vary from about $\frac{1}{4000}$th to $\frac{1}{2000}$th of an inch in diameter; the smallest appear smaller than blood-corpuscles, but it is to be remembered that they are capable of elastic expansion, and that the blood-corpuscles change their shape in traversing narrow channels. They intercommunicate so as to form a continuous network with meshes which vary in different tissues. Thus, the lungs have the widest capillaries arranged in the closest meshwork, while poorly vascular tissues have narrow capillaries and the meshes large.

Capillaries are often described as consisting of endothelium and having no other wall proper to them, but this description is misleading, for there is a homogeneous membrane quite distinct from the endothelium. The endothelium, the lines of contact of whose scales can be brought into view by the action of silver nitrate, and can also be seen by successful carmine staining (Fig. 5), has much less prominent nuclei than those in the arterioles; but capillaries everywhere exhibit, regularly disposed on them, other oval nuclei little flattened. These were known before the endothelium had been detected, and belong to corpuscles embedded in a homogeneous wall. This may be conveniently termed, as it sometimes is, the *tunica adventitia*, being continuous with the tunica adventitia of the arteries. The endothelial scales are pointed at the extremities, most of them diamond-shaped; but those placed at a bifurcation may have three points, one projecting toward each channel.

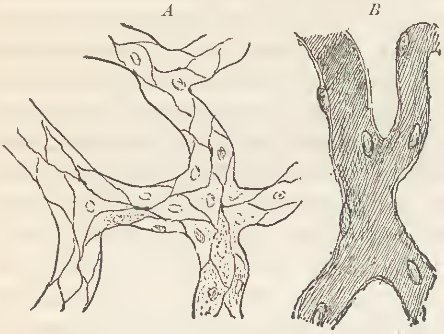


FIG. 59. — CAPILLARIES. *A*, Endothelial wall; *B*, homogeneous wall, with oval nuclei.

The veins have a total sectional area, for the return of the blood, greater for each part than that of the arteries. Arteries are very generally accompanied by veins, but there are many subcutaneous veins in the neck and limbs without corresponding arteries. In the limbs specially there is a notable system of subcutaneous veins, which allows the blood to return when the deep veins are pressed on by muscles in contraction. The return is facilitated by the frequent anastomoses of veins even of considerable size, and in the extremities by the arrangement that in the upper limb below the level of the axilla, and in the lower limb below the knee, the main arteries are each accompanied by two anastomosing veins termed *venae comites.* There is one exception to the rule that the veins beginning in the capillaries are continued into larger and larger trunks, namely, the portal vein, which, receiving blood from the intestines, spleen and stomach, breaks up in the liver into branches ending in a second set of capillaries, through which the blood passes to the hepatic veins.

The walls of veins are much thinner and greatly more distensible than those of arteries, the difference in thickness depending on the circular muscular fibres being much less developed, or even, in some veins, absent. The tunica intima presents the three elements found in the arteries, namely, endothelium, delicate connective tissue and elastic membrane; but the latter is very thin and adherent to subjacent connective tissue. The tunica adventitia in its deeper part, in a number of veins, presents a well-marked development of longitudinal muscular fibres, and longi-

tudinal muscular fibres are also found in the deeper part of the middle coat. In the middle and outer coats the elastic tissue takes mostly the form of longitudinal fibres.

A remarkable peculiarity of veins consists in the presence of *valves* in most of them. These are thin transparent membranous folds projecting into the interior, often not visible when lying against the wall of the vein, but nevertheless of great tenacity. They are mostly arranged in pairs, which form pouches with their mouths directed towards the heart, although single folds occur, attached to the margins of veins opening into larger channels. Their free edges are straight, and their attached margins deeply curved. When the pouches are distended with fluid pushed back from the cardiac side, the parts of the folds nearest to the free edges are pressed one against the other so as completely to block the channel; and by this means regurgitation of blood is prevented, while also all attempts to inject fluid from the main trunk into veins furnished with such valves are rendered futile. The strength of the valves depends on white fibres regularly arranged as in aponeurosis, those nearer the edge coursing parallel to the edge, and those further back slanting in different directions so as to decussate. Their endothelial scales are elongated longitudinally on the exposed side, and transversely within the pouches. Valves are most numerous in the veins of the limbs, especially the lower. They are absent from the small veins under $\frac{1}{12}$th inch in diameter, and from the pulmonary, mesenteric, splenic, portal, hepatic, renal and uterine veins, also from the ovarian vein; but they are found in the spermatic. Moreover, they are absent from the veins of the head and neck, with the exception of the subclavian and external jugular, and the opening of the internal jugular into the subclavian.

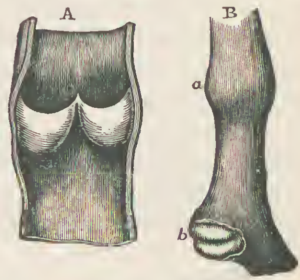


FIG. 60. — VALVES OF VEINS. *A*, vein laid open to show the two pouches of a valve; *B*, unopened vein showing — *a*, the dilatation opposite a valve; *b*, a closed valve seen from distal side.

Owing to the thinness of their walls, veins when empty are more easily completely flattened than arteries, and while the ordinarily constructed arteries require accurate compression against bone to arrest the circulation in them, veins are closed against the passage of blood by every accidental pressure, such as the swelling of contracted muscles. Thus muscular action throws the blood of the limbs into the subcutaneous veins, and thus also the valves render the variations of external pressure important factors in aiding the return of the blood towards the heart, since they are effective to move it in that direction but not in the other. The thinness of the walls and the paucity of circular muscular fibres cause divided veins to gape much more than arteries, in consequence of continuity of the outer coat with loose surrounding tissue.

Development of bloodvessels. As all vessels originate from simple beginnings, and as the muscular, white-fibrous and yellow-elastic tissues are developed in the walls of the larger vessels exactly as in the other situations, the question left to consider is the origin of capillaries. The first walls of bloodvessels, both in the area vasculosa of the embryo and in textures developing later, may be said to be of the nature of a cell-wall. In the area vasculosa branched corpuscles undergo proliferation, and when the centrally placed progeny are developed into blood-corpuscles those round about are flattened against the cell-wall. Other similar corpuscles are connected by branches with the wall of the first, and the channel of communication enlarges so as to make one continuous hollow. Other unwalled corpuscles become connected in series, and flatten out at the same time that they throw out a continuous tubular wall, on the interior of which the series is arranged. There may be difficulties to explain in connection with the details of this process, but it is impossible to admit the accuracy of the descriptions which account for the formation of the vessels by the coming together of vacuoles or cavities hollowed in the interior of the protoplasm of corpuscles. The outer layer of the amnion in young mammalian embryos admits of easy staining, and is highly favourable for the studying of developing vessels. In it one may observe that new vessels are formed from the unwalled corpuscles of the tissue in the way described, and that when the form of the capillary is completed it exhibits a series of distinct flattened corpuscles, the first endothelial scales, with spaces between them and a perfectly continuous homogeneous wall outside, against which other corpuscles may press. The advancing extremity of a vessel in progress of formation is sometimes widely open, as for instance in the cases of the new vessels underneath surfaces of ossification from cartilage.

Fig. 61. — Formation of Capillaries from connective-tissue-corpuscles round the amnion of an embryo lamb, one inch long.

ABSORBENT SYSTEM.

Under this name are comprehended a system of vessels and spaces by means of which substance is poured directly into the great veins to be mingled with the blood and, connected with those vessels, solid structures called lymphatic glands.

The absorbent vessels are divisible physiologically into two sets, *lymphatics* and *lacteals;* but there is no anatomical distinction between the

two save that which is topographical. Lymphatics begin in the textures, and bring back from them a clear fluid termed *lymph.* The lacteals are the lymphatics of the mucous membrane of the small intestine, and receive substances brought from the intestinal cavity into the interior of the villi, by the absorbent action of living corpuscles. It is principally by this means that fatty substances are introduced into the system. These substances being in the form of exceedingly small globules or molecules give to the watery fluid which conveys them a milky appearance, and on that account the fluid is called *chyle*, and the vessels which contain it are termed lacteals.

Lymph is a clear coagulable fluid, containing nucleated corpuscles. The corpuscles are most abundant in lymph which has traversed lymphatic glands, and correspond generally in character with colourless blood corpuscles; but many of them are smaller and with more distinct nucleus. Chyle is simply lymph with addition of fatty and other substances derived from the contents of the intestine.

Lymphatic vessels, including lacteals, may be divided into three sets, viz., capillaries, simple walled tributaries, and trunks. The *capillary lymphatics* are minute vessels, forming networks like the capillary bloodvessels, but, both as respects the vessels themselves and the size of the meshes, much more irregular in size and shape. They have no tunica adventitia, but are simply spaces lined with endothelium. The endothelium itself differs from that of blood-capillaries in the scales of which it is composed having characteristic undulating margins. The *simple walled tributaries* receive the lymph from the capillary lymphatics, and differ from them in being considerably larger, in having endothelial scales more elongated and less undulating in outline, and in having valves. The stronger walls and the presence of valves indicate the presence of a supporting membrane.

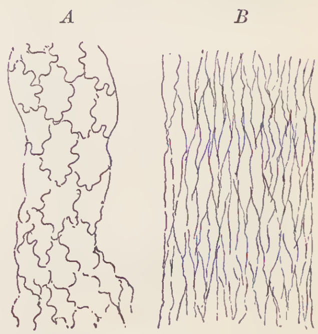


FIG. 62.—LYMPHATICS. *A*, Capillary; *B* simple walled tributary.

The **lymphatic trunks** are vessels with three walls, like veins and arteries, viz., a tunica intima of endothelium supported by fibrous tissue, a tunica media of circular muscular fibres, and a tunica adventitia of white and yellow-elastic fibres, in bundles taking all directions. They are all supplied with valves, consisting of white fibrous pouches in pairs, like those of veins; and they yield opposite the valves, so as to present when distended a somewhat beaded appearance, the valves succeeding one another with much greater frequency than those of veins.

In the limbs, head and neck, and walls of the trunk, the lymphatic trunks are arranged in deep and superficial sets, the deep sets accompanying

bloodvessels, and the superficial arranged on the surface of the body in long independent courses. With the exception of the main vessel, the thoracic duct, which is the size of a crowquill, they are, all of them, thin, white, or transparent threads. Thus the lacteals in the mesentery are with difficulty seen against the light when empty, till a dissection is made and then by the collapse of their walls they show as whitish threads, like the lymphatics elsewhere when dissected out. Lymphatic trunks are supplied with bloodvessels which take a longitudinal course in their coats.

FIG. 63.—LYMPHATIC GLAND of the groin. *a*, Afferent duct with concavities of valves turned toward the gland; *bb*, efferent ducts with the convexities of their valves toward the gland. (After Mascagni.)

Besides the networks of capillary lymphatics, *lymph spaces* lined with endothelium are found in various situations, for example, surrounding the funiculi of nerves and on the surfaces of tendons. In the frog there are undoubted perivascular spaces of this sort round the mesenteric vessels, and in the human subject there seems reason to believe that similar spaces surround vessels in the substance of the brain.

The most remarkable connection of the lymphatic system with spaces is the opening of lymphatic vessels into serous membranes. This is found, in the case of the peritoneum, on the under surface of the diaphragm, and in the case of the pleura, opposite the intercostal spaces. A number of endothelial cells of the serous membrane are arranged in a rosette around the opening of the lymphatic, and such openings are called *stomata*.

Some anatomists still feel difficulty in determining whether the lymphatic system is completely closed in with endothelium, or is in direct continuity with the interstices of the connective tissues. The practical point is certain that lymphatics can be injected by puncturing with hollow needles, and throwing coloured fluids into the tissues; and there seems no reason to doubt that while diffusible substances pass through the walls of the capillary bloodvessels, the lymph is the accumulation of less diffusible substances remaining in the interstices of the tissues to be pressed onwards by every local pressure into the valved lymphatics. The walled lymphatics are certainly in continuity with unwalled spaces in the lymphatic glands, and there is no radical distinction between lymphatic glands and diffuse retiform tissue. Also, by injecting with the puncture-syringe, large spaces can be brought into view, surrounding the acini of racemose glands and the tubules of the testes and kidneys; from them the injection passes on into the walled lymphatics.

Lymphatic glands. These structures, called also *lymphatic ganglia, conglobate glands* and *lymphatic kernels,* are essentially masses of retiform or adenoid tissue interpolated in the course of lymphatic vessels. They vary from the minuteness of a pinhead to three quarters of an inch in length, and more than half an inch in greatest breadth, and in an irritated or inflamed condition may attain much larger dimensions. They are surrounded by fibrous capsules, which are most separable in young subjects, but connected in all both with the connective tissue around and with trabeculae passing inwards. They present, on section, a uniform appearance to the naked eye. They receive afferent lymphatic trunks, which travel some distance in contact with the capsule and divide into smaller vessels before dipping in at different parts of the surface; and at one part there is usually a depression or hilus where arteries enter, and veins and efferent lymphatics emerge; the efferent lymphatics gathering immediately into larger trunks. On examination under the microscope, two sets of structures are seen, trabecular stroma and corpuscles. The trabeculae are white fibrous bundles, continued in from the capsule, and form a meshwork whose bands get finer while the meshes get smaller from the surface towards the centre of the gland. Scattered muscular fibres have been found in them, and, in various animals, continuous muscular bands. Within the undisturbed meshes of this network the whole space seems filled with minute leucocytes, but when a number of them have been washed away, or when the section has been stretched, there is left a mass of such leucocytes or lymph-corpuscles closely adherent to one another, and a reticulum of branched corpuscles separating it from the trabeculae. The corpuscles of a lymphatic gland are thus of two kinds, the lymph-corpuscles and the branched corpuscles. The coherent mass of lymph-corpuscles presents, in the centre of the gland and opposite the hilus, the form of a network of *cords* or *cylinders* interarching with a

Fig. 64.—Section of Human Lymphatic Gland, highly magnified, showing the crowded corpuscles of the medullary cylinders and the retiform tissue of the lymph-paths with its branched corpuscles.

network of spaces of similar dimensions to themselves, while at the periphery it forms rounded *nodules* or *bulbs*, each connected by a neck with the cylinders. The peripheral part containing the bulbs is sometimes termed the *cortex*, and the deep part the *medulla*. Around the bulbs the reticulum is distinct, and though considerably supported by homogeneous substance investing the branching corpuscles, yet exhibits manifest open passages or *lymph-paths*; and outside the reticulum the main trabeculae form *alveoli* corresponding with the bulbs. In the medulla neither the trabeculae, reticulum nor lymph-paths are so distinct; but the spaces between the cylinders are crowded with lymph-corpuscles, the protoplasm of which is more abundant than in those of the cylinders. Both afferent and efferent lymphatics, when followed into the gland, are seen to lose their proper walls and to be continuous with the unwalled lymph-paths.

Closed follicles. It has been customary to class along with the lymphatic glands certain minute nodular collections of small unwalled corpuscles similar to those of the lymphatic glands, and likewise situated in meshes of retiform tissue, namely, the closed follicles of the digestive tract. These are rounded bodies like small grains, with definite capsules. They are situated in the mucous membrane, and are provided with a special distribution of capillary blood-vessels within them, which are directed toward the centre and form loops emerging at some distance from their entrance. They have an abundance of lymphatics round them; but there is no evidence that their corpuscles migrate into either the lymphatics or bloodvessels. They have latterly been described by some as *lymphatic nodules.* Mere nodules of unwalled corpuscles do exist, as, for example, in the mucous membrane of the stomach and bladder, but differ from closed follicles in having neither special bloodvessels nor distinct boundaries. The vague use of the word 'lymphatic' is, however, to be deprecated. From both lymphatic glands and from diffuse retiform tissue there can be no doubt that corpuscles travel into lymphatic vessels; but the researches of Stohr (1884 and 1891) have shown that a characteristic feature of the closed follicles of the tonsils and the back of the tongue is the passage of leucocytes from them through the epithelium of the mucous membrane. Thus the evidence is in favour of closed follicles being organs of elimination, and a rational explanation is suggested of their importance in disease.

SACCULAR MEMBRANES.

Considering the direct communication of serous membranes with lymphatics by stomata, as above described, and the formation, by mere breach of continuity of connective tissue, of other sacs comparable to the interstices with which the origins of lymphatics are connected, the characters which such spaces present may be here considered.

Serous membranes are so named because their lubricating surfaces present the appearance of being moistened with a thin watery fluid. Under this name are included the membranes derived from the walls of the primitive space or coelom separating, in the embryo, the splanchnopleure from the somatopleure, namely, the peritoneum, the pleurae, the pericardium and the tunica vaginalis. The cavities inclosed by these four membranes are portions of one original space. They all consist of a parietal and visceral layer continuous one with the other where the parietal layer turns inward to be folded round the surface of the organ, or organs, invested by the visceral layer. They are practically shut sacs, but in the female the Fallopian tubes open into the peritoneum, and in certain fishes and reptiles there are other openings termed the abdominal pores. Generally the serous membrane can be stripped with ease from the wall or viscus which it clothes, and is seen to consist of homogeneous connective tissue, strengthened with curling elastic fibres and lined with endothelium; but there is no distinct line of separation between the fibrous tissue of the ovary or that of the tunica albuginea testis and their serous coverings. Serous membranes are the seat of acute pain when inflamed, and minute branches of nerves have been traced to them.

In addition to the membranes mentioned, the arachnoid used to be described as a serous membrane with a parietal and visceral layer; but latterly the custom has become general to confine the name arachnoid to the transparent membrane over the pia mater, to term the opposed surface the deep surface of the dura mater, and to call the intervening cavity the subdural space. Nevertheless the subdural space is walled by two surfaces lined with endothelium, and is not without communications with the lymphatics. It is not, however, developed from the coelom or any primitive cavity, but is hollowed out in previously continuous tissues in the same way that synovial membranes are.

Synovial sacs. The synovial membranes of joints have already been considered with the other textures of articulations ; but besides these there are sacs differing from them in presenting a membrane of uninterrupted continuity round every part of their cavity, while resembling them in secreting a similar synovial moisture liable, like theirs, to become glairy under inflaming influences. They are of two sorts, *bursae mucosae* and *thecae* or *vaginal membranes*. Bursae are thin-walled sacs, intervening most frequently between muscle or tendon on the one side, and a bony surface on the other. The largest bursae intervene, one of them between the gluteus maximus and the great trochanter of the femur, and the other between the deltoid muscle and acromial arch on the one hand, and the shoulder joint with the immediately surrounding insertions of muscles on the other. The bursae beneath the ligamentum patellae, the tendo Achillis and the radial insertion of the biceps muscle, are examples of bursae between tendon and bone. There are likewise subcutaneous bursae, the most constant being that over the patella, the inflammation of which con-

stitutes housemaid's knee, and another at the olecranon, the inflammation of which is called miner's elbow. A theca differs from a bursa in more completely investing a tendon or tendons, and in being bound down by the strong fibres which complete the canal in which the tendons are made to move freely by its aid. A tendon may be completely surrounded by the membrane, the investing portion of the theca not being continuous with the parietal, save at its extremities, where the one part turns on the other like the finger of a glove reflected on itself, or the tendinous and parietal layers may be connected by bands of connection, *vincula*. The radical similarity of synovial membranes of joints, bursae and thecae is well illustrated by the bursa under the subscapularis muscle and the theca of the long head of the biceps flexor radialis, both being prolongations of the synovial membrane of the shoulder joint. Bursae and thecae have not even the imperfect endothelial lining described in connection with synovial membranes of joints. Pacinian corpuscles (p. 81) have been found in connection with bursae and sheaths of tendons.

INTEGUMENTS.

The integuments consist of the tough vascular and sensitive *corium* covered superficially with a stratified epithelium, the *epidermis*, and passing on its deep aspect gradually into subcutaneous areolar tissue.

The *subcutaneous areolar tissue* or *superficial fascia* varies in amount and density in different parts of the body. In the eyelids, in the penis in the male, and in the nymphae in the female, it is free from adipose tissue; but in other parts it is pervaded with it, constituting the rete adiposum, which reaches its greatest development in the gluteal region. The subcutaneous tissue in most places permits a gliding movement of the skin on the deeper parts; but in the palms of the hands and the soles of the feet, vertically placed bundles knit the skin inseparably to the palmar and plantar aponeurosis; and the scalp is in like manner bound down

Fig. 65.—Cutaneous Ligaments of Phalanges of finger. *a*, The strong parts of the sheaths of the flexor tendons; *bb*, insertions of ligaments.

to the aponeurosis of the occipito-frontalis muscle. Also from the sides of the phalanges in both hand and foot, as I have pointed out (1867), there extend obliquely upwards from the lower ends, and downwards

from the proximal ends, strong bands to the skin, so as to fix more or less firmly in different individuals the integument on the back of each phalanx, and accumulate over the backs of the joints the wrinkles caused by extension. The subcutaneous tissue of the scrotum is characterized by a continuous layer of unstriped muscular fibres, the *dartos*, which effects its contraction under the influence of cold.

The corium or *cutis vera* consists of a stroma of tough gelatiniferous substance, apparently uniform toward the surface, but breaking up more deeply into thick bands of white fibrous substance, which, followed from their origin, are at first closely reticulated and felted, and afterwards form meshes of greater size the deeper they are, till ultimately the thick bands break up into thin fibres of ordinary connective tissue. The deeper meshes are in most places filled with grains of adipose tissue, so that in dissecting the skin away from the texture immediately beneath, a honey-comb of white fibrous tissue is exposed, with fat or semi-transparent jelly in the spaces, according as the subject is well nourished or emaciated.

The surface is everywhere thrown into minute elevations termed *papillae*, and the superficial part of the corium is therefore indicated as the *papillary*, and the deeper as the *reticulated stratum.* Especially in the reticulated stratum there is a great development of curling yellow-elastic fibres, often with highly intricate coils; and it is this tissue which by its resilience causes wounds to gape, and the flaps in surgical operations to shrivel to a much smaller size than they had when mapped out before being raised. There is also a great abundance of connective-tissue-corpuscles in the corium, spindle-shaped in the deep parts and with several branches more superficially.

At the very surface, investing the papillae and intervening parts, I find a continuous network of small stellate corpuscles connected with one another by their branches. The papillae are little elevations, which, over the surface of the body generally, have a nodular form not exceeding $\frac{1}{500}$th inch in length, and are scattered irregularly. In each there is a loop of bloodvessels, and in some there is in addition a touch-corpuscle. On the lips they are larger and crowded together. Under the nails they are likewise crowded, much elongated, pointed, and sloped in the direction in which the nail grows. On the palmar aspect of the hand and fingers, and on the sole of the foot, they are finger-like processes exceeding $\frac{1}{100}$th inch in length, arranged in ridges each of which presents a double row of tufts of papillae, while dotted in single file down the

Fig. 66.—Ridges of Integument of Thumb, with a single row of orifices of sweat-glands in the middle of each.

middle of each ridge are the orifices of sweat-ducts at regular distances one from another. The pattern of these ridges is seen on the surface of the epidermis, and presents differences on the tips of the fingers of different individuals, which have been recommended as marks useful for identification of criminals. The regular arrangement of the papillae and sweat-glands, together with absence of hairs and sebaceous glands, and great thickening of the epidermis, are peculiarities of the palm of the hand and sole of the foot. The bloodvessels of the corium distribute their capillaries to the papillary stratum, every papilla containing a capillary loop; consequently superficial scratches and abrasions bleed copiously. By this arrangement an abundance of papillae brings a large amount of blood within reach of the epidermis; but abundance of blood at the surface is not always accompanied with thickness of cuticle: the cuticle of the lips is thin. Muscular fibre, although not an essential part of the corium, occurs in connection with it. Striped muscular fibres are found where striped muscles are inserted into the skin, as in the chin; and unstriped muscular fibres are much more widely distributed in connection with hairs and sweat-glands, and are described as occurring in the prepuce and about the nipple.

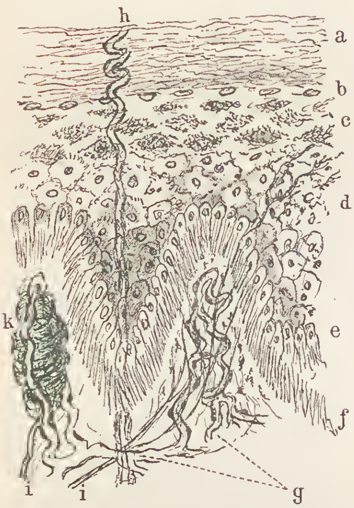


Fig. 67.—Vertical Section of Epidermis and Cutis Vera of front of finger. *a*, Horny epidermis; from *b* to *e*, growing epidermis; *b*, stratum lucidum; *c*, stratum granulosum; *d*, polyhedral strata with prickle-cells; *e*, columnar stratum with striated appearance dependent on elongated processes; *f*, surface of cutis vera squeezed separate from the epidermis, and exhibiting in this locality interdigitating processes; *g*, capillary bloodvessels passing up into two papillae; *h*, orifice of sudoriparous duct which shows the spirality of the duct in the horny epidermis; *i*, nerve breaking into fine branches; *k*, touch-corpuscle.

The epidermis, *cuticle* or *scarfskin*, is a stratified squamous epithelium varying much in thickness on different parts of the body. It is broadly divisible into two great layers, namely, the growing part and the part converted into horn, readily separated one from the other by accumulation of moisture, whether from over-irritation of the deep corpuscles during life, which constitutes blistering, or from incipient putrefaction after death.

The growing epidermis, called also *rete mucosum* or *layer of Malpighi*, is soft and easily stained with carmine. Its corpuscles are of different forms at different depths. Resting in contact with the corium, there is a single layer of vertically elongated corpuscles, and superficial to them are those of smallest size, which are of similar breadth, but rounded or polyhedral in form. Passing still towards the surface, the corpuscles get larger and flatter till the deep limit of the horny layer is reached, where they become suddenly quite scaly and horny. The elongated or columnar stratum

exhibits, where the skin is thick, a vertically striated appearance, and on closer examination each of its corpuscles may be seen to consist of a part divided into finger-like processes resting on the corium and a distal portion in which the nucleus is placed. This layer is the chief seat of pigment in the negro and in the dark portions of the skin in the white races. My observations lead me to believe that Schneider (referred to by Sharpey) was probably right in supposing that the columnar corpuscles by perpetual division of their nuclei give rise to more superficial corpuscles of the epidermis, notwithstanding that, as I showed many years ago, the corpuscles of the epithelium of the cornea arise by proliferation superficial to the elongated layer; but the subject has not been sufficiently worked out.

FIG. 68.—EPITHELIUM OF CORNEA OF OX. *a*, Superficial scales; *b*, young cells; *c*, large cells with digital processes; *d*, deepest cells; *e*, degenerated cells with nucleus wasted away; *f*, with nucleus partially wasted; *g*, young cells proliferating.

In the *polyhedral strata* a spiny appearance of the margins of the corpuscles may be detected, whence they have been called *prickle-cells*. The spines of adjacent corpuscles do not fit into one another, but are formed by adhesion at intervals, with breaches of continuity between (Martin, 1875). In the most superficial corpuscles subjacent to the horny layer, not only is there considerable flattening, but the protoplasm has become altered and granular, imbibing carmine more easily than the subjacent younger corpuscles, and constituting a *stratum granulosum*.

The horny epidermis consists of scales which are more or less completely converted into keratin, the chemical substance which forms the characteristic component of horn. It is impervious to ordinary carmine-staining, with the exception only of the nuclei of its deepest lamina (*stratum lucidum*), which continue to absorb the dye readily, while the substance round them is unaffected. In its other laminae the nuclei are more difficult to detect, but by suitable manipulation they can generally be brought more or less distinctly into view. This is easiest in situations where the epidermis is very thin, the scales being more delicate in such situations. In the stratified squamous epithelium of the buccal mucous membrane, which is essentially the same structure as epidermis, the superficial scales continue to show a distinct nucleus, and granules in the substance round about. Even in the negro the horny epidermis is destitute of pigment.

Cutaneous glands. These are of two kinds, sudoriparous and sebaceous. To these might be added the mammary glands, but they are so specialized that it is better to consider them with the reproductive organs.

The *sudoriparous* or *sweat-glands* are found all over the body. They are simple tubes, with the secreting part convoluted in the form of a ball from which a straight duct proceeds. The convoluted portion and the commencement of the duct are lined with simple cubical epithelium. Occasionally, *e.g.* in the heel, the sweat-glands are bifurcated. They lie in spaces in the deepest part of the corium, or in the subcutaneous tissue, not all at the same depth, but some with shorter ducts than others. When the horny epidermis is stripped off and examined on its deep surface, hair-like processes are seen projecting from it which are tubular prolongations lining the sweat-ducts for some distance. The horny scales of these prolongations lie edgewise to the surface of the skin, toward which they are gradually pushed, and as they pass up among the corpuscles of the growing epidermis, the unshrinking tube which they form is thrown into a spiral by the continual flattening of the corpuscles around, so that, in places where the horny epidermis is very thick, as in the heel, as many as four or more turns like a corkscrew may be seen. The sweat secreted by the sudoriparous glands, though mainly a watery fluid with salts in solution, is not destitute of oil on the palmar aspect of the hands where there are no other glands; and oil appears to be more abundant in the sweat of the armpits, where the sudoriparous glands are very large. The ceruminous glands, which secrete the wax of the ear, are largely developed convoluted tubes like sweat-glands.

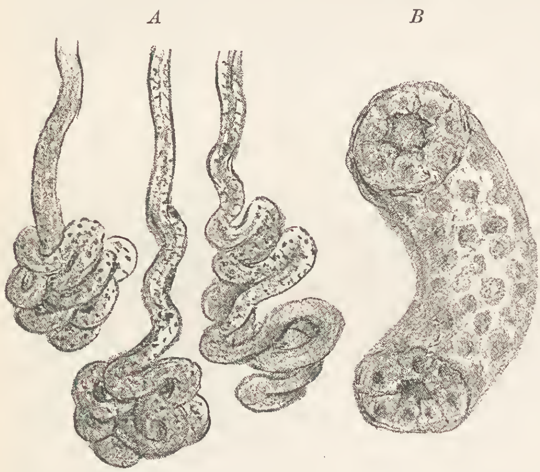


FIG. 69.—SUDORIPAROUS GLANDS. *A*, Coiled secreting portions of three glands with first parts of their ducts; *B*, portion of coiled tube more highly magnified.

The sebaceous glands are of the racemose type, presenting dilated pouches. They are always associated with a hair. Where the hair is large, as on the scalp, they open, one or two of them, a short way down the neck of its follicle, and are little more than simple saccules, with an inclination to lobulation; but the hair may be small, and, especially on the lips and nose, may be situated at the opening of a larger sebaceous gland, the duct of which may divide more than once before terminating in rounded dilatations. The secreting epithelial cells are so flat that they may be termed squamous.

Special epidermal growths of two sorts occur in the human subject,

namely, nails and hairs. Both are accompanied with subsidiary arrangements of the corium and epidermis around.

Nails. A nail is essentially a thickened shield of horny epidermis pushed forwards from within a fold of integument, and remaining in contact with the corium for some distance. The part of the corium with which it is united is called the matrix. In the fold of the matrix two papillary surfaces covered with epidermis are turned toward one another, and the closely set pointed papillae, both in the fold and on the rest of the matrix, are all directed toward the tip of the nail. Within the fold one mass of horny substance is formed from the growing epidermis clothing the deep and the reflected surface of the fold, so that at this part, the *root*, the nail is hardest in the middle depth; but as soon as it escapes from the fold, it receives new layers of corpuscles on its deep surface only, and hence the exposed part of the nail is hard on the surface and softer beneath, while it gets thicker gradually toward the free extremity. If left uncut the nails turn over and tend to break into laminae, in consequence of the continued contraction of corpuscles after separation from the matrix. The individual scaly corpuscles of which the nails are formed are slightly elongated in the direction of growth of the nail.

Fig. 70.—Sebaceous Gland of Cheek. Opposite *B* a hair-follicle, containing a small hair, opens into the duct. (Toldt.)

Hairs. A hair is an epidermal growth based on a single papilla. It projects from a deep invagination of the skin, termed a hair follicle, and consists of two parts, viz., the root and the shaft. *The root* or *bulb* is a dilated and rounded mass of spherical corpuscles surrounding an enlarged papilla, and at its upper part showing the different textures found in the shaft. *The shaft* of a fully developed hair presents three textures—the cortical substance, the epithelium and the medulla. The cortex or cortical substance is badly named; it is no mere bark, but constitutes the main structure. It is formed of horny epidermal scales much elongated, and incapable for the most part of being fully separated even with the aid of liquor potassae. But hairs of the head and beard tend to split at their extremities, and it is easy in such a case and in hairs of the armpit to exhibit fibres. *The epithelium* (so called) is a single layer of unelongated

scales on the surface of the cortex so arranged as to have the appearance of a network, each scale having its advanced edge convex and free, while its lower edge is covered by the next scale. The free edges project very slightly in the human subject, but to such an extent that when two hairs laid side by side pointing in opposite directions are rubbed between finger and thumb, they move each in the direction of its root. To see the epithelium on the shaft properly a hair should be cleansed with chloroform and examined in air; but over the root it is much thicker, the scales being much more closely imbricated. The *medulla*, in the centre of the shaft, is a column of uncompressed and unelongated corpuscles having a granular appearance and often containing minute air-globules. It is not developed in the small hairs over the body; and in many persons with fine hair is absent even from the hairs of the scalp, or occurs in interrupted patches. It is easily studied in split hairs from the beard. *Pigment* occurs in very variable degree in hair, and where present is most abundant in the root. In the shaft it is more abundant in the cortex than in the medulla, and is found both in the granular form and evenly diffused. It is granular in black and brown hair, and a diffused staining in red hair. But hairs of a brilliant shade have the additional peculiarity that the medulla is well developed and full of minute air-globules which reflect the light. A certain proportion of such, mixed with a larger number of a duller hue and with less-developed medulla, are sufficient to warm up the apparent effect of the whole. The silvery white of old age owes its brilliance to the same cause, and one may sometimes see a hair swollen with air and white in one part of its extent, while it is slenderer and coloured in a portion above or below. The essential part of the whitening of the hair from age is the disappearance of the pigment, which usually takes place simultaneously with the development of air in the medulla, and often, in individual hairs, in a single night. The form of the shaft of the hair varies both in different

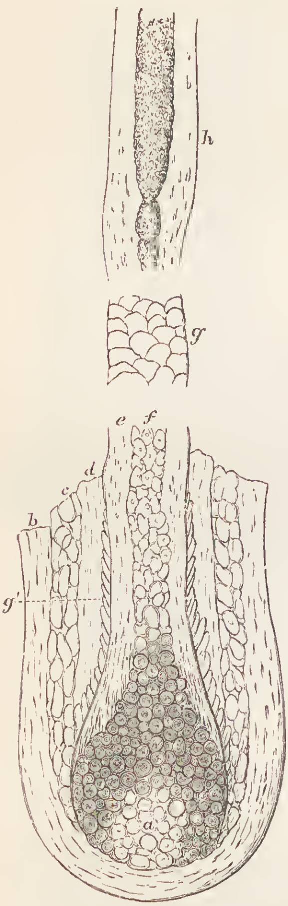


Fig. 71.—Hair. *a*, Papilla covered by cells of the bulb; *b*, follicle; *c*, *d*, outer and inner cuticular sheath, the imbricated layer not being represented; *e*, cortex; *f*, medulla; *g*, epithelium; *g'*, epithelium in optical section; *h*, part of hair becoming white by disappearance of pigment from cortex, and the diameter of the hair increased by evolution of air in the medulla.

races and in different parts of the body. In straight hair it is cylindrical, in curly hair somewhat flattened, and in woolly hair quite strap-shaped. The flattest hairs are those of the armpit.

The hair-follicle is the depression which lodges the root and lower end of the shaft of the hair. It is an invagination of the corium, and is lined with an invagination of the epidermis, termed the *root-sheath.* The follicle has three distinct layers: (1) the external or peripheral coat of closely felted fibres, with the insertion of the erector muscle connected with it; (2) a middle dense coat, with nuclei elongated transversely; and (3) an internal homogeneous membrane. The sheath presents in contact with the follicle a continuation of the deep part of the epidermis, and internal to this three distinguishable layers continuous with the horny epidermis, viz.: (1) a layer of scales with no perceptible nuclei, named after Henle; (2) a layer with distinct nuclei, associated with the name of Huxley; (3) an imbricated so-called epithelium of the sheath, with the free edges of its scales directed downwards, continuous below with the epithelium of the hair itself. The hair-follicles are sloped, being arranged round various points and lines. Those of the scalp form a whorl round the vertex; those of the trunk incline towards the middle line in

Fig. 72.—Vertical Section of Scalp, showing two roots of hairs. *a*, *a*, Bloodvessels; *b*, *b*, erectores pilorum; *c*, *c*, sebaceous glands.

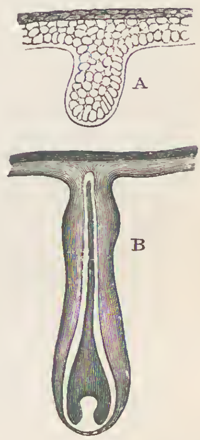


Fig. 73.—Development of Hair. *A*, Downward growth of epidermis; *B*, form of the hair completed. (After Kölliker.)

front and behind; in the male a line, absent in the female, extends up from the pubis; in the limbs the slope is downwards. On the side toward which the hair is inclined, there is a band of unstriped muscle, *erector pili*, descending from the corium at a little distance obliquely to near the lower end of the follicle, and tending to elevate the hair into the erect position. The action is well illustrated in the hair of a horse when taken ill, the coat losing its gloss and standing up.

Hairs begin to appear in the third month of foetal life. A thickening of the epidermis in connection with a papilla dips down into the corium; in the lower part of this mass of cells the hair appears with a slender shaft and a large bulb into which a papilla projects, and after being so elongated as sometimes to be folded on itself, bursts through to the surface. The hair which covers the infant at birth, *lanugo*, falls out and is replaced by a new growth. Hairs appear to be reproduced in two ways, namely, by a new growth on the same papilla, or by the formation of a new papilla near the bottom of the follicle.

ORGANS OF COMMON SENSATION.

The skin being the principal seat of common sensation, the organs of common sensation may be conveniently examined now, even although some of the most sensitive surfaces, such as the conjunctiva and the covering of the tongue, have claims to be considered as mucous membranes; and some of the organs to be considered, such as Pacinian bodies, are not confined to the neighbourhood of free surfaces.

Fig. 74.—Vertical Section of Skin of Sole of Foot, with ramification of nerves in stratum Malpighii. The stratum corneum is only shown in its deepest parts. Gold preparation. (Kölliker.)

In the integuments, the terminal organs of nerves become smaller the nearer they are to the surface.

Epidermal endings. Exceedingly fine ramifications of nerves can be traced, by means of metallic staining, between the growing corpuscles of the epidermis; but with regard to their exact mode of termination there is room for further investigation. In various situations in the lower animals the ramifications have been followed to disc-like expansions or other corpuscular terminations, but in the human epidermis it is not clear that they end otherwise than in intercellular threads. Branching cells in the epidermis were brought under notice by Langerhans, but are generally thought to have no connection with nerves. More probably they are wandering corpuscles seeking the surface.

Touch-corpuscles of Wagner or of Meissner. These are bodies found in papillae of the corium, most abundantly in the hand and foot, especially on the flexor aspects of the fingers and toes, and also in the skin of the nipple, the red borders of the lips, the tip of the tongue, and the tarsal part of the conjunctiva. Each occupies a considerable bulk of the centre

Fig. 75.—Vertical Section of Skin of Sole treated with gold, showing numbers of cells of Langerhans, but no nerves. (Kölliker.)

Fig. 76.—Touch-Corpuscles very highly magnified, with two medullated nerve-fibres entering it. (Kölliker.)

of the papilla in which it is contained, and has the appearance of a firm oval or pyriform mass, on the surface of which one or two nerve-fibres lose their medullary sheaths. Within them there are numbers of nucleated corpuscles (*touch-cells*), transversely elongated, with septa between them; and the axis-cylinder of the nerve breaks into branches which pass in between the cells. Similar organs, with a small number of more distinct transversely-arranged touch-cells, have for a long time been known on the edges of the bills of ducks and other birds, *corpuscles of Grandry* or of *Merkel*.

End-bulbs of Krause. These are found in the sclerotic conjunctiva, mucous membrane of the cheeks and epiglottis, and the papillae of the tongue, glans penis, glans clitoridis and nymphae; also in the synovial

membranes of the joints of the fingers. They are rounded bodies, with

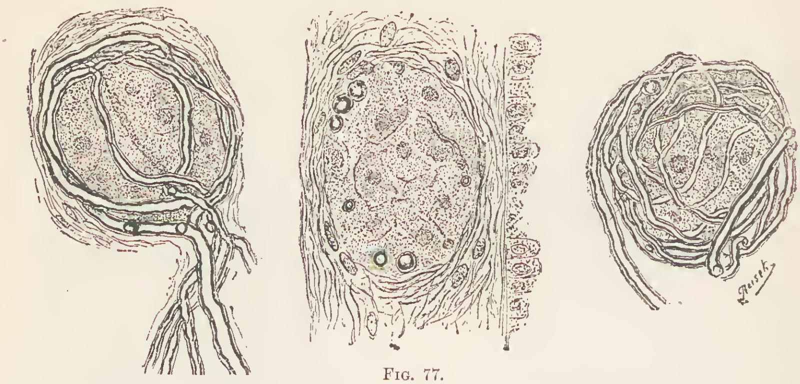


Fig. 77.

Fig. 78.

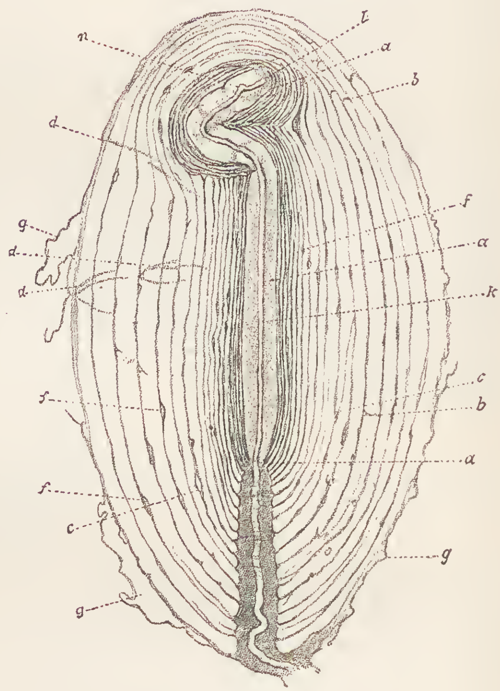


Fig. 79.

Fig. 77.—Rounded End-Bulbs from human conjunctiva. *A*, With five nerve-fibres entering; *B*, vertical section through the same end-bulb, showing the touch-cells and sections of nerves, and to the right conjunctival epithelial cells; *C*, end-bulb with beautiful winding of the nerve-fibres. (Toldt.)

Fig. 78.—Cylindrical End-Bulb from conjunctiva of calf. (Toldt.)

Fig. 79.—Pacinian Body, human. *a*, Core; *b*, *c*, transverse and longitudinal connections between the capsules; *d*, separated fibres of capsules; *f*, nuclei; *g*, adherent connective tissue; *k*, nerve-fibre inside the core; *l*, its extremity; *n*, a branch. (Kölliker.)

a nucleated sheath, containing within them delicate, unwalled, nucleated corpuscles, and receiving one or more nerve-fibres which coil round them.

These bulbs are comparable in this respect with Wagner's touch-corpuscles; and there are some of them, called *genital corpuscles*, on the glans penis (*q.v.*), more nearly allied to touch-corpuscles; but there are others, the *cylindrical bulbs* of Krause, which have an axis-cylinder passing up the centre, and are in that respect comparable with Pacinian bodies.

Pacinian bodies. These are bodies which were observed by Vater, and distinctly described by Pacini. They may be as much as $\frac{1}{12}$th inch in length, but are more frequently considerably smaller. They occur most abundantly on the digital nerves on the front of the hand, lying among the grains of fat in the subcutaneous tissue. They are found also in the walls of joints and bursae, and in other situations, as behind the head of the pancreas. They are often seen to great advantage in the mesorectum of the cat. They are oval laminated bodies, developed round a single nerve-fibre. The successive laminae or capsules are separated by endothelial layers, and are closely connected at the base with the primitive sheath of the nerve-fibre. The nerve-fibre, piercing into the interior of this system of capsules, loses its medullary sheath, and on entering the innermost capsule becomes surrounded by a somewhat granular substance, the *core*, and ends towards the further extremity of the core in a single knob, or after bifurcation or slight branching.

MUCOUS MEMBRANE.

This is the name given to the lining membrane of internal passages freely communicating, directly or indirectly, with the outside, and pouring out on their surface moisture containing a larger or smaller quantity of *mucus*, a colloid substance whose characteristic constituent, named mucin, contains nitrogen, but no sulphur, and is completely soluble in lime water. It is liable, especially under the influence of catarrh, to be loaded with corpuscles of variable size. These are simply migratory corpuscles which have made their way to the surface. There are three great tracts of mucous membrane—the alimentary, the respiratory and the genito-urinary. Mucous membrane, like integument, presents an epithelium. This is of a stratified squamous description from the oral aperture to the entrance of the stomach, and in some other localities, as the urethra, the urinary bladder and the conjuctiva; while it is columnar from the entrance of the stomach as far as the deep sphincter ani, ciliated in the respiratory tubes, and of various characters in other places. The mucus from which the membrane is named is undoubtedly poured out by more than one kind of epithelium, and in some places, as in the mouth, the bronchi and the biliary passages, there are special glands which have a mucous secretion. The mucous membrane proper, subjacent to the epithelium, presents, close to the surface, a homogeneous, gelatiniferous matrix, rich in bloodvessels, and in its deeper part may pass rapidly into

ordinary fine connective tissue with few, if any, capillaries devoted specially to its nourishment. But in the case of the stomach and intestines there is a distinct definition of the deep limit of the mucous membrane afforded by a thin but firm muscular layer, the *lamina muscularis mucosae*, and the whole structure superficial to this is highly vascular for the supply of simple tubular follicles supported by retiform tissue.

It may be noted, in comparing mucous membrane with integument, that while epidermis is uniformly epiblastic in origin, and the hypoblast of the embryo is entirely devoted to the development of epithelium of mucous membrane and its glands, the genito-urinary epithelium is in part mesoblastic in origin, and that of the conjunctiva, lachrymal duct, nares, palate, gums and lining of the cheeks are epiblastic. Nor does the tendency to become dry or to pour out mucus on abnormal exposure depend on the source of development, seeing that in such circumstances the vagina becomes dry, while the urinary bladder pours out mucus; and in the case of the conjunctiva the tarsal part remains moist, while the corneal epithelium becomes dry and opaque.

EMBRYOLOGY

OR GENERAL DEVELOPMENT.

The young animal owes its origin to the union of germs or essential products of reproduction of the male and female parent. The male germ is the spermatozoon, the female germ is the ovum.

The human *spermatozoon* is a body with a firm pyriform head comparable with a nucleus, and a fine thread-like tail which propels it with an eel-like movement, the whole reaching to $\frac{1}{500}$th inch in length.

Ova, at a certain stage of their development, have a general community of structure, being in fact largely developed nucleated corpuscles, provided with protoplasm, nucleus, nucleolus and cell-wall. The protoplasm is termed the *vitellus* or *yelk*, the nucleus the *germinal vesicle*, the nucleolus the *germinal spot*, and the cell-wall the *vitelline membrane* (*zona pellucida* or *zona radiata*). But while this comparatively simple condition is retained in the ova of many invertebrate animals and in Amphioxus, there is added to the protoplasm or formative yelk in the ova of all vertebrata above Amphioxus a greater or less amount of nutrient yelk in globules and granules containing the characteristic substance lecithin and more or less uniformly diffused in the protoplasm or accumulated in mass. The abundance, paucity or absence of nutrient yelk leads to the enormous differences of size in the ova of different animals, and also to great apparent differences in the process called cleavage which is the first to take place after impregnation. In non-mammalian vertebrata, excluding

Amphioxus from the term, the formative yelk accumulates on the upper side or animal pole, and the ovum has been termed *telolecithal*. In osseous fishes and amphibians the formative yelk passes round on the surface of the nutritive yelk. In ova of the largest sort, such as those of birds, it is more distinctly confined to a limited area called the *cicatricula*, about ¼th inch in diameter in the hen's egg, marked by a paler colour of the yelk; and it is within this area that the changes prior to and immediately succeeding impregnation take place. These distinctions deserve attention even from the human anatomist, as many details of embryology are conveniently studied in the ova of amphibians and birds.

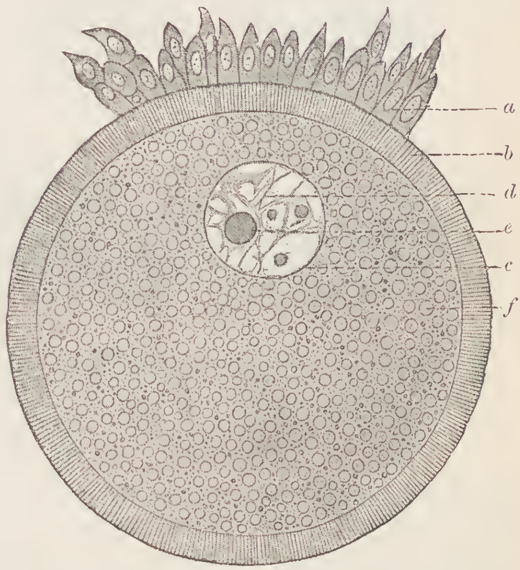


FIG. 80.—OVUM OF RABBIT. *a*, Follicular cells; *b*, zona pellucida; *c*, germinal vesicle; *d*, network within it; *e*, germinal spot; *f*, yelk. (Hertwig, after Waldeyer.)

Maturation of ovum. After attaining its full size, the ovum undergoes changes preparatory to impregnation, which have been specially studied in holoblastic invertebrate ova, such as those of the sea-urchin and the star fish. The germinal vesicle, which has approached towards one side of the ovum, begins to lose its regular form; and first the germinal

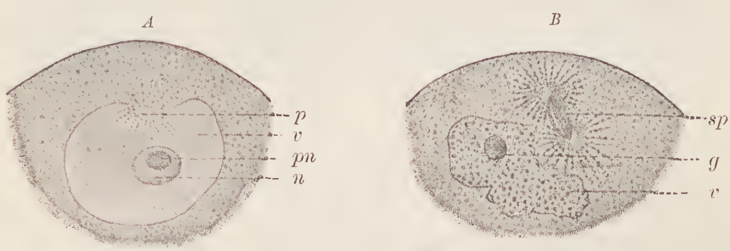


FIG. 81.—CHANGES OF GERMINAL VESICLE IN ASTERIAS GLACIALIS. *A* shows a protrusion of protoplasm with rays piercing *v*, the germinal vesicle, while the germinal spot has become divided into two substances, viz., *pn*, paranuclein, and *n*, nuclein. *B* shows *v*, the germinal vesicle shrivelled, its membrane gone; *g*, the germinal spot dwindling; and *sp*, a nuclear spindle fully formed. (Hertwig.)

spot, and then the germinal vesicle disappears. While this is going on, two starlike arrangements, united to form the poles of a spindle, make their appearance in connection with the germinal vesicle, and one pole of the spindle turns round till it comes in contact with the surface of the yelk and

is gradually separated by constriction from the other half, constituting what is called the *first polar body*. The remaining half of the spindle is again

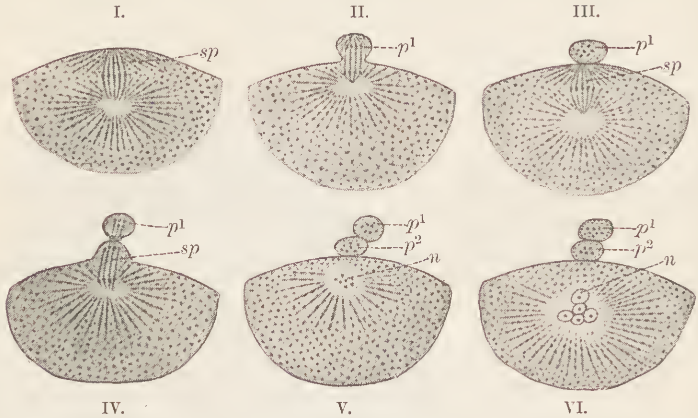


FIG. 82.—FORMATION OF POLAR BODIES IN ASTERIAS GLACIALIS. I. The nuclear spindle, *sp*, approaches the surface. II. One half the spindle is projected in an elevation. III. The elevation is separated as first polar body, p^1, and the inner half of the original spindle becomes again a complete spindle. IV. This spindle is protruded in one half its extent. V. The protrusion becomes the second polar body, p^2. VI. The deep part of the spindle becomes the nucleus, *n*, of the ovum. (Hertwig.)

converted into a complete spindle, and a second time one half is projected from the surface of the yelk and separated to produce the *second polar body*. From the half of the spindle which remains within the yelk

FIG. 83.—IMPREGNATION, ASTERIAS GLACIALIS. *A*, An elevation occurs opposite the nearest spermatozoon; *B*, the elevation of the yelk and the head of the spermatozoon are pressed together; *C*, the spermatozoon enters. (Hertwig, after Fol.)

after the extrusion of the second polar body, a small nucleus is formed which retires towards the centre of the yelk, and remains as the nucleus of the unimpregnated ovum, the *female pronucleus* of v. Beneden, a structure comparable in size rather to the germinal spot than to the germinal vesicle.[1]

[1] The polar bodies have been made to play an important part in the theories of Balfour and Weismann, as so much extruded material carrying with it certain powers of growth, whether sexual, hereditary or other. But the polar bodies are not excreted products; they have a structural origin distinctly pointing them out as

Impregnation, as observed in starfishes and threadworms, is effected by a single spermatozoon which outruns the others. The surface of the yelk rises to meet the spermatozoon; the spermatozoon pierces into the interior, and loses its lash, while its head increases in size. It is now called the *male pronucleus*; it becomes the centre of a radiate arrangement of the yelk, rapidly approaches the female pronucleus and becomes fused

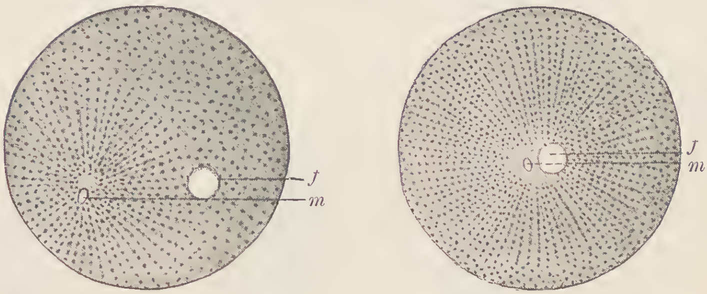


FIG. 84.—IMPREGNATED OVUM OF SEA-URCHIN. The male and female pronucleus, *m* and *f*, approach. (Hertwig.)

with it, to form the nucleus of the impregnated ovum. In mammals a number of spermatozoa pierce the zona pellucida.

Cleavage. The nucleus of the impregnated ovum becomes the starting-point of a series of multiplications of nucleated corpuscles by fissiparous division, known as *cleavage* or *segmentation*, which may be *equal* or *unequal*. In unequal segmentation the first cleft extends from one spot, and the process goes on most rapidly in that neighbourhood. In amphibia and in certain fishes the segmentation, though unequal, involves the whole ovum, which

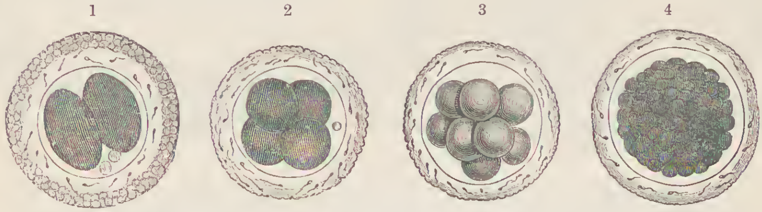


FIG. 85.—STAGES OF CLEAVAGE. Ova of bitch from Fallopian tube. Spermatozoa cling to the zona pellucida. 1, Shows division of yelk into two masses, as also the two polar bodies; in 4 the morula stage is reached. (Kölliker, after Bischoff.)

is therefore classified, like ova undergoing equal segmentation, as *holoblastic*. But in the teleosteal and elasmobranch fishes segmentation is partial, not including the whole circumference, and the ovum is called *meroblastic*. The

organisms. They are aborted ova, as pointed out by Mark, Butschli, Boveri and Hertwig (Hertwig, *Entwicklungsgeschichte*, 4th edition, p. 40). Each spindle is an organism dividing into two; the process is therefore an intervention of two generations between the original female germ and that which undergoes impregnation. Recognized parthenogenetic ova have only one polar body; but they are not the only ova with this peculiarity, for Amphioxus is found by Sobotta (1895) to have likewise only one.

extreme of the meroblastic arrangement is exemplified in birds, segmentation in them being confined to the small *germinal disc* or *cicatricula.* In mammals, monotremata excepted, the ovum is holoblastic and segmentation is equal. The two nuclei derived by mitosis from the first nucleus seek the centres of the masses around them. The process is repeated in each of these masses, and again in their progeny, so that the two unwalled nucleated corpuscles arising from the first division of the yelk are con-

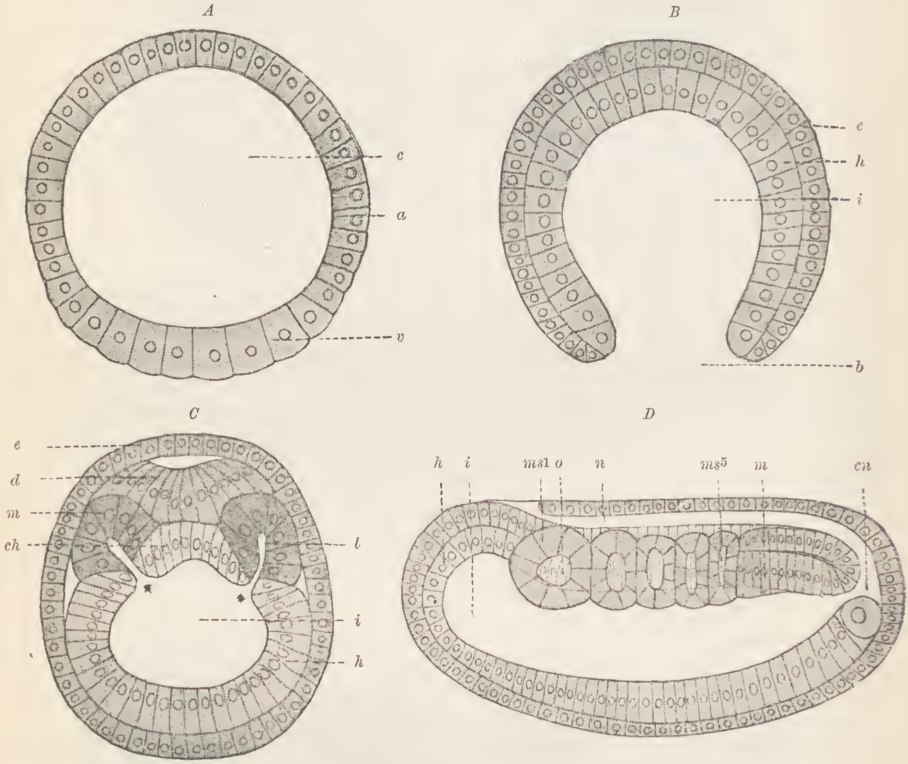


Fig. 86.—Amphioxus. *A*, Germinal membrane: *c*, cleavage cavity; *a* and *v*, animal and vegetative cells. *B*, Gastrula: *e*, epiblast; *h*, hypoblast; *i*, primitive intestine; *b*, blastopore. *C*, Transverse section of embryo with five mesoblastic somites; *e*, epiblast; *d*, medullary plate; *m*, mesoblast; *ch*, notochord; *l*, wall of lateral pouch which is converted into half the coelom; *i*, intestinal cavity; **, entrances to coelom afterwards obliterated; *h*, hypoblast. *D*, Longitudinal section about same period: ms^1, ms^5, first and fifth mesoblastic somites; *o*, hollow of mesoblastic somite; *n*, neural canal; *cn*, canalis neurentericus; other letters as before. (Hertwig, after Hatschek.)

verted into four, the four into eight, the eight into sixteen, and so on. In this manner is formed what is called the *morula* or mulberry mass. Within the morula a cavity is formed by the determination of corpuscles to the surface, accompanied in the case of mammals with an absorption of fluid leading to considerable enlargement of the ovum. The resulting condition is known as the *blastoderm* or *germinal membrane.*

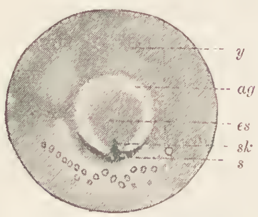
Formation of layers and embryo. *In Amphioxus,* a development starting from this stage takes place, more easily comparable with what has been

seen in the invertebrate form Sagitta than with what is found in the vertebrata, but deserving attention from the manifest affinity of Amphioxus to vertebrata, and because it throws light on vertebrate development. The corpuscles of the blastodermic membrane are arranged one cell deep in a complete sphere. One half of the sphere becomes invaginated within the other so as to produce the cuplike form known to naturalists as the *gastrula*, the inclosing half constituting the *epiblast* or *ectoderm*; and the invaginated part the *hypoblast* or *entoderm*. The mouth of the gastrula becomes contracted into a small aperture, the *blastopore*. The spinal cord is formed from before backwards out of a portion of the ectoderm, which is folded into a groove and then into a cylindrical canal with the blastopore situated at its posterior end, so as to make a continuous passage from the central canal of the spinal cord to the cavity of the gastrula, the *neurenteric canal*, destined to be subsequently obliterated. The entoderm becomes divided into four parts, viz.: (1) beneath the spinal cord, a dorsal strip which is converted into the notochord; (2) the digestive tube running down the middle; and (3 and 4) two lateral pouches given off at the fore part or blind end of the elongated gastrula, and expanding as they pass backwards, so that they come together on the dorsal and ventral aspect of the digestive tube. Each of these lateral pouches becomes shut off from the digestive tube and is flattened out so as to present two layers, a visceral and a parietal, and also is divided into a dorsal and ventral portion, the dorsal part being broken up from before backwards into a series of segments, the *mesoblastic somites*, while the ventral part unites with its fellow and bounds the *coelom* or body-cavity. Thus, the whole mass resulting from cleavage is engaged, in Amphioxus, in the formation of the embryo.

All other Vertebrata differ from Amphioxus, in respect that at no time does the blastoderm present the simple gastrular form. But in all of them, the blastoderm passes into a *bilaminar* condition, comparable with that produced by invagination in Amphioxus; and in all a blastopore can be made out, whose correspondence with that of Amphioxus is evidenced by its being situate behind the subsequently appearing *medullary groove* or first indication of the cerebro-spinal axis, in such a position that, even in mammals, the representative of a neurenteric canal has been traced.

In the bird's egg, before hatching, the cicatricula exhibits a clear part, *area pellucida*, which presents an *ectoderm* of vertically elongated and an *entoderm* of flattened corpuscles, and is bounded peripherally by a thickened *germinal wall* or *area opaca*. Already also, there is to be seen, at the margin toward which the caudal end of the embryo is to be directed, a cresentic thickening, the *sickle*, from the front of which, when hatching commences, a knob projects, with a groove appearing behind it. In a few hours there is formed from the knob a longer thickening, the *primitive streak*, with a depression, the *primitive groove*, running down the middle. Subsequently the *medullary folds*, joined

together in front and bounding the medullary groove, appear in a thickened part in the middle of the cicatricula, and grow backwards, pushing back the primitive streak behind them.



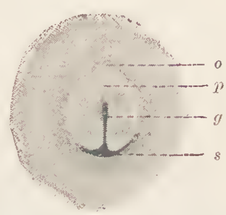


FIG. 87.—TWO SUCCESSIVE STAGES OF AREA GERMINATIVA of hen's egg in the first hours of hatching. *A. y*, Yelk; *ag*, area germinativa; *es*, embryonal shield; *s*, sickle; *sk*, sickle-knob. *B. o*, Area opaca; *p*, area pellucida; *g*, primitive groove; *s*, sickle. (Hertwig, after Koller.)

In the mammalian ovum, the blastodermic membrane is spherical, and presents a single layer of corpuscles; but, unlike the arrangement described in Amphioxus, it has adherent to its deep surface at one part a mass of other corpuscles of rounded form, differing from those which form the membrane in being granular instead of clear. This granular heap becomes flattened out, and, in the part where it adheres, the *area embryonalis* appears as a white thickening. The most deeply placed corpuscles now become distinguished as a single layer of flattened cells, the *entoderm*;

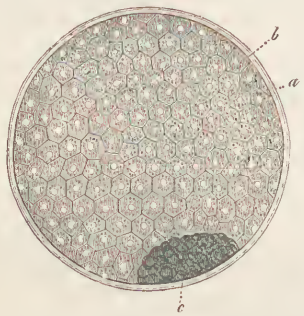


FIG. 88.—THE BLASTODERM, uterine ovum of rabbit. *a*, Zona pellucida; *b*, blastoderm; *c*, heap of cleavage-corpuscles. (Kölliker, after Bischoff.)

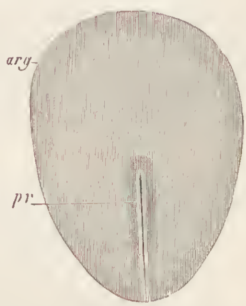


FIG. 89.—AREA EMBRYONALIS of rabbit, eight days after impregnation. *ary*, Boundary of area; *pr*, primitive streak and groove. (Kölliker.)

while the remainder, the *ectoderm*, distinct from the entoderm, consists of cubical cells, covered at first with others of flattened form, *Rauber's layer*, destined soon to disappear in a manner still disputed. The complete separation of ectoderm and entoderm gradually extends round the whole ovum. The thickening of the area embryonalis belongs entirely to the ectoderm. At first circular, it elongates to an ovoid form, and from its narrower extremity a *primitive streak* extends forwards, in connection with whose expanded hinder end a minute *blastopore* has been observed (Heape). In front of the primitive streak the *medullary folds* appear as in the bird.

Subsequently, in all vertebrates, an intermediate layer appears between the ectoderm and entoderm, and thus there come to be three layers of the embryo, known as *epiblast*, *mesoblast* and *hypoblast*. The mesoblast makes its appearance in connection with the primitive streak, and the primitive streak is epiblastic. But epiblast and hypoblast are closely united in the middle line, and it is difficult to determine the precise source of the rounded corpuscles of which the mesoblast is composed.

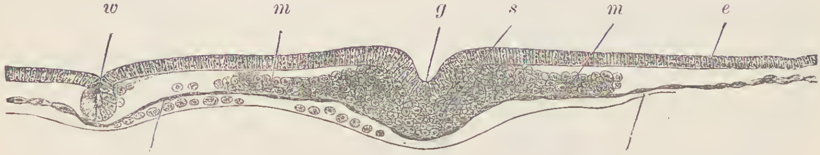


Fig. 90.—Transverse Section through the middle of Primitive Streak of Embryo Chick of the stage shown in Fig. 86, *B*. *e*, Epiblast; *h*, hypoblast; *m*, mesoblast; *g*, primitive groove; *s*, primitive streak; *w*, boundary wall of germinal area. (Hertwig, after Koller.)

The theory of Hertwig, according to which the mesoblast represents the lateral pouches of the entoderm of Amphioxus, is supported by researches on Triton, which show that in that animal the mesoblast, beneath the blastopore, originates as a pair of flattened sacs whose walls form a visceral and a parietal layer. The speedy separation of the mesoblast more or less completely into two layers in all vertebrates is comfirmatory

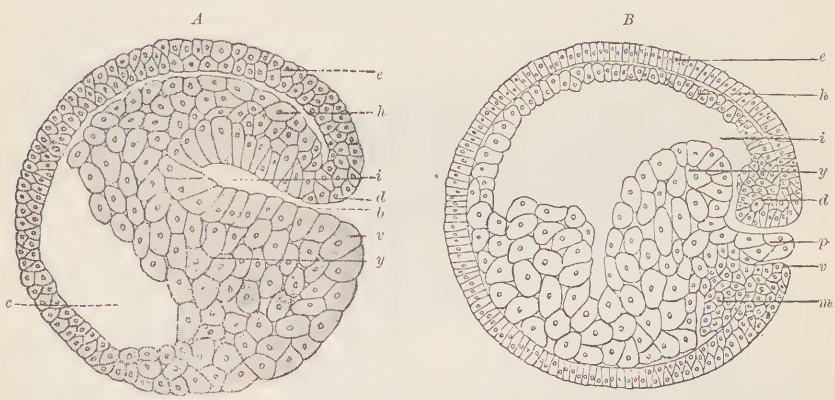


Fig. 91.—Longitudinal Sections through Ova of Triton, showing *A*, the commencement of gastrular invagination; *B*, completed gastrulation. *e*, Epiblast; *h*, hypoblast; *m*, mesoblast; *i*, primitive intestine; *b*, blastopore; *p*, yelk-plug of blastopore; *d* and *v*, dorsal and ventral lips of blastopore; *y*, yelk-cells; *c*, cleavage-cavity or cavity of germinal membrane. (Hertwig.)

of the Hertwig view. But not the whole of what is included in the term mesoblast, as generally understood, is thus accounted for, according to the Hertwig theory. Beyond the outline of the embryo proper, separated from it by a clear space, *area pellucida*, there is, in the germinal wall in the chick, and adherent to the entoderm in the mammal, a zone of granular corpuscles sending out branches and giving origin to the first

blood-corpuscles as well as to the walls of bloodvessels; and these extend inwards and form the *area vasculosa.* Hertwig so far adopts a view previously put forward by His as to consider this growth independent of the parietal and visceral layers of the mesoblast, and that it is the sole source of the blood, connective tissues and skeleton; and he gives it the name *mesenchyma.* According to this, it is only the epithelia, glands, bounding surfaces, nervous system and muscles that are developed from the three recognized layers, while the bloodvessels, connective tissues and skeleton have a peripheral origin. Certainly it is a fact and worthy of note that the blood and structures connected with the development of the blood appear in a centripetal manner contrasting with the centrifugal origin of the form and special organs of the embryo.

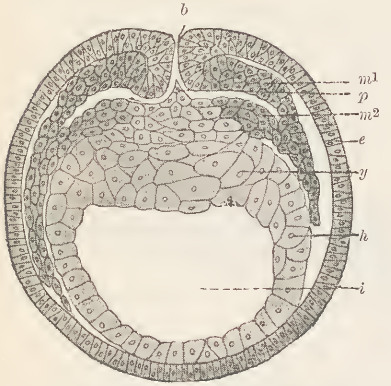


FIG. 92.—TRANSVERSE SECTION OF OVUM OF TRITON passing through the blastopore *b.* m^1 and m^2, Parietal and visceral walls of mesoblastic sac; *e*, epiblast; *p*, yelk-plug; *y*, yelk-cells; *h*, hypoblast; *i*, intestine. (Hertwig.)

The medullary folds, as already indicated, are two elevations of epiblast united in front, which elongate backwards and turn over to unite one with the other in the middle line and convert the furrow between them, the *medullary groove*, into a closed cylinder, the rudimentary cerebro-spinal axis. Immediately after closure, the fore part of the cylinder exhibits three dilatations, the *first, second* and *third cerebral vesicles*, which go to form the brain, while, on the sides of the foremost, two lateral lobes appear, the *primary optic vesicles*, destined to take part in the formation of the eyes.

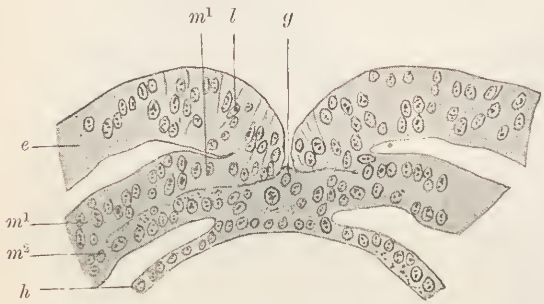


FIG. 93.—TRANSVERSE SECTION THROUGH A HUMAN GERMINAL AREA with open medullary groove, in the vicinity of the neurenteric canal. *e* and *h*, Epiblast and hypoblast; m^1 and m^2, parietal and visceral laminae of mesoblast; *l*, lip of primitive groove, *g*. (Hertwig, from Graf Spee.)

FIG. 94.—EMBRYO CHICK AND GERMINAL AREA during first day of hatching. Fresh, vitelline membrane not removed. *a*, Anterior limiting sulcus; *m*, united medullary folds; *pr*, primitive streak and groove.

The remainder of the cylinder is developed into spinal cord. At the edge of the medullary groove, as it closes and becomes separated from the rest

FIG. 95.—CHICK AND GERMINAL AREA OF ABOUT 24 HOURS. Fresh. The medullary folds more extensively united in the head. The four first segments of the neck distinct, with the medullary folds at their level still open. Beneath this, the part in which succeeding segments have to be developed, and, still lower, *pr*, the primitive groove.

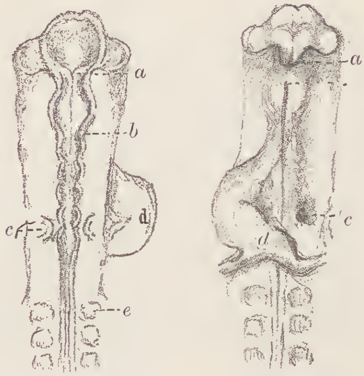


FIG. 96.—FORE PART OF CHICK OF 36 HOURS. Alive. *A*, Dorsal view: *a*, front of optic commissure, with first cerebral vesicle and primary optic vesicles above it, and second cerebral vesicle below; *b*, constriction between second and third cerebral vesicle; *c*, auditory pit opposite the division between the fourth and fifth compartments of the third cerebral vesicle; *d*, heart; *e*, first mesoblastic somite. *B*, Ventral view: *a*, bifurcating flexed extremity of first cerebral vesicle; *b*, notochord; *c*, auditory pit; *d*, heart.

of the epiblast, there is an everted margin whence spring the nerves and spinal ganglia.

The notochord. Beneath the medullary groove, immediately after its commencement, a rod-like structure makes its appearance in the middle liné, dimly visible from the surface, but seen in section to be deeply placed. This is the *notochord* or *chorda dorsalis,* round which the bodies

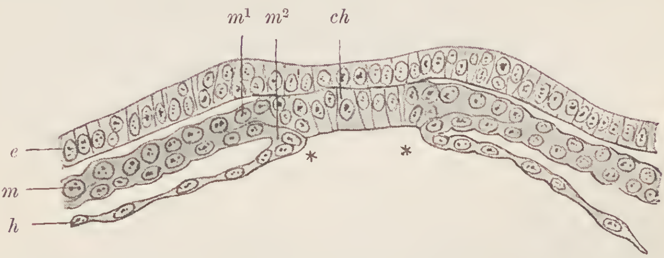


FIG. 97.—TRANSVERSE SECTION OF EMBRYO RABBIT, showing—*ch*, commencing notochord continuous opposite * and * with *h*, the hypoblast, and m^1 and m^2, the parietal and visceral layers of the mesoblast. (Hertwig, from E. van Beneden.)

of the vertebrae are afterwards developed. It is at first continuous on each side with both hypoblast and mesoblast; but it becomes rapidly separated from the hypoblast and converted into a rod-like structure between the right and left halves of the mesoblast. Posteriorly, it is continuous with the epiblast at the blastopore or neurenteric canal. The

notochord becomes surrounded by a sheath, from which are continued the *membrana reuniens superior* round the neural canal, and the *membrana reuniens inferior* round the visceral cavity; and thus is formed the *membranous vertebral column.* In fishes and amphibians it undergoes further development, its texture presenting large membranous vesicles or cell-walls in juxtaposition, like the cellulose cell-walls of plants. In the lamprey and sturgeon it is developed into a large cylindrical structure in a stout sheath of circular and longitudinal fibres. In most fishes it has an interrupted form in the adult, constituting the jelly between the vertebral bodies. In mammals it entirely disappears, except so far as it takes part in the formation of the central parts of the invertebral discs.

Zones and segments. To the sides of the neural axis, and passing round it in front, there soon make their appearance two *zones*, the *paraxial* and the *lateral*, distinguished by a difference in the development of the mesoblast. The mesoblast of the paraxial zone, the *dorsal plate*, is thick and separated by a deep and a superficial groove from the lateral zone. That of the lateral zone, the *lateral plate*, splits into a superficial or parietal and a deep or visceral layer, between which is the space constituting the *coelom* or body-cavity, afterwards divided into the sacs of the pericardium, pleura and peritoneum. The superficial or cutaneous layer forms, with the cuticular epiblast and the subsequently intruding muscular layer, the *somatopleure*; while the deep is the musculo-intestinal layer, and adhering to the hypoblast forms the *splanchnopleure*, from which the digestive tube is developed. After the first day's hatching in the chick, and about the eighth day after impregnation in the rabbit, there appear in the paraxial zones, behind the part destined as brain, a pair of dense patches, rapidly followed, as development proceeds, by successive pairs behind them, till the appearance is given of a double range of square blocks on the dorsum of the embryo. These are the *protovertebrae* of older writers, more properly termed *mesoblastic somites.* In the newt it is made out very distinctly not only that each of these consists of a hollow inclosed by a single layer of cells, but that the hollows are originally continuous with the coelom, and their walls with the two layers of mesoblast bounding it. This is not, however, in all vertebrates so apparent. In both birds and mammals each somite consists of a dense mass of corpuscles, and in mammals the hollows are minute. These somites are specially concerned

FIG. 98.—LIVE CHICK OF 48 HOURS. *a*, In front of second primary cerebral vesicle; *b*, between the second and third; *c*, auditory pit between the fourth and fifth compartments of the third cerebral vesicle; *d*, heart; *e*, opposite the first mesoblastic somite, that of the occipito-atlantal segment; *f*, thalamencephalon; *g*, hemisphere; *h*, olfactory pit. At the lower part the primitive streak and groove are still visible.

in the formation of the voluntary muscles. While in some animals this takes places in greater part from the lower and inner walls, in birds it is principally from the roofs that the *muscle-plates* are formed. The material for the formation of the bodies and arches of the vertebrae lies to the inside of the mesoblastic somites, and that for the transverse processes and costal arches forms a bar beneath the fore part of each muscle-plate, while the spinal ganglia, though developed, as above noted, from epiblast, come to occupy a position beneath the hinder part of each muscle-plate; and thus all these parts were supposed by Remak to be developed from the protovertebrae. Perhaps it were well to include them all in such a term as *primitive segment*, and to reserve the expression mesoblastic somite for the structure which, so far as persistent, is converted into muscle.

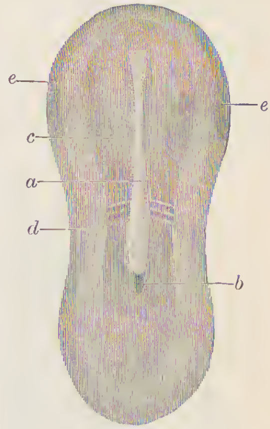


FIG. 99.—EMBRYO RABBIT OF 8 DAYS AND 4 HOURS, $\frac{20}{1}$. *a*, Medullary groove; *b*, remains of primitive streak; *c*, axial zone with two mesoblastic somites; *d*, paraxial zone; *ee*, first indications of heart. (Kölliker.)

It has been found in elasmobranch fishes that mesoblastic somites are not only developed in series backwards from the first pair, which constitutes the first muscular segment of the neck, but also forwards in the head. As many as nine of these have been described, the foremost being alleged to form the rectus superior, rectus inferior and obliquus inferior muscles of the eyeball, the second the obliquus superior, the third the rectus externus. The fourth, fifth

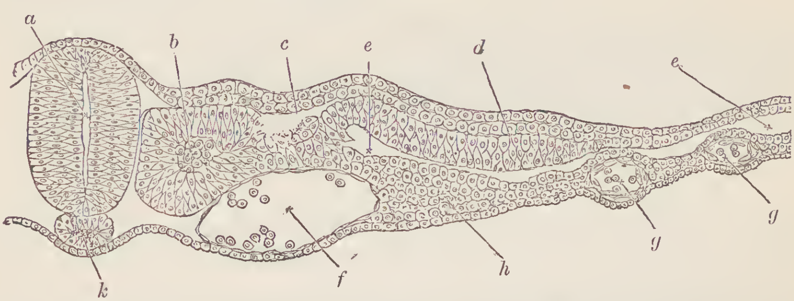


FIG. 100.—TRANSVERSE SECTION THROUGH DORSAL REGION OF EMBRYO CHICK OF 45 HOURS. *a*, Medullary canal; *b*, mesoblastic somite; *c*, Wolffian duct; *d*, somatopleure; *e*, pleuroperitoneal cavity; *f*, aorta; *g*, bloodvessels; *h*, splanchnopleure; *k*, notochord. (Hertwig, from Balfour.)

and sixth are said to disappear, while the three hindermost go to form the muscles uniting the head to the shoulder-girdle (Milnes Marshall). Further, in elasmobranchs, the coelom has been traced forwards into the head, in the visceral arches hereafter to be described; and the walls of these prolongations are supposed to form the muscles of mastication and the branchial muscles. But before forming a final judgment with reference

to the muscular segments of the head, further information is probably required. Thus it would be desirable to know the relation of the muscular segments overlying the skulls of the pleuronectid fishes to the segments of the skeleton, and to the muscles of the eyes and jaws.

Parietes and mucous tract. It will already have been seen how largely the formation of organs is due to the folding of blastodermic layers with free surfaces. The freeing of the outline of the embryo from the rest of the ovum, as well as the inclosure of the viscera, is also due to folding of these layers. By local extension of superficies, the blastoderm is folded in under the margins of the cerebral vesicles; and by that means, as well as by its own growth, the fore part of the embryo is projected free into a hemispherical depression, *the anterior limiting sulcus*, long before the hinder part has been laid down. But gradually the extremities of this sulcus are carried backwards, and ultimately the coccygeal end and sides of the embryo are surrounded, and the somatopleure gathered together both laterally and longitudinally, so as to complete the walls of the body and converge to a narrow neck at the umbilicus. Meanwhile the splanchnopleure, consisting of the hypoblast, and deep layer of the mesoblast, is folded in, after the same fashion but more closely, and the part in front forms a tube, the *fore-gut*, extending forwards and ending blindly beneath the third cerebral vesicle, while the part behind forms a similar cul-de-sac, the *hind-gut*. Thus, the digestive-tube is gradually pinched off from the yelk-cavity, of whose walls it originally formed part. The neck of communication remains as the *vitelline duct*, and the yelk-sac beyond is in mammals known as the *umbilical vesicle.* The vitelline duct soon becomes elongated and closed, being thus converted into a cord by which the omphalo-mesenteric vessels are conveyed to and from the walls of the yelk-sac. Neither mouth nor anus is a primary opening. There is every reason to believe the blastopore or neurenteric canal to be phylogenetically the one communication of the digestive cavity with the exterior; but, however that may be, the oral and anal apertures are of late appearance and both of them produced by rupture

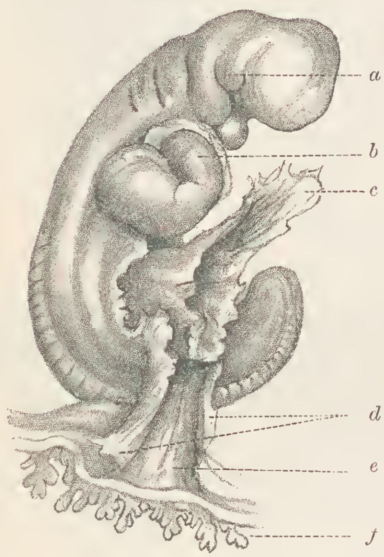


FIG. 101.—HUMAN EMBRYO, $\frac{16}{1}$, prior to bending forward of brain at back of fourth ventricle. *a*, Maxillary lobe, and below it the mouth bounded by the first or mandibular arch with the first three branchial clefts beyond; *b*, heart; *c*, umbilical vesicle torn across; *d*, torn edges of amnion; *e*, allantois; *f*, tufts of chorion destined to become placental. (After His.)

of epiblast and hypoblast at points somewhat removed from the terminal extremity of the gut. The vitelline duct comes off from the digestive tube in the course of the small intestine, and the spot is sometimes indicated in the adult subject by the occurrence of a diverticulum situated at a distance varying from four feet to eighteen inches from the ileo-colic valve. The respiratory tubes and the biliary ducts both begin from the fore-gut as mesial ventral culs-de-sac, dividing into right and left branches and continuing to ramify. Arising from the ventral aspect of the extremity of the hind-gut is

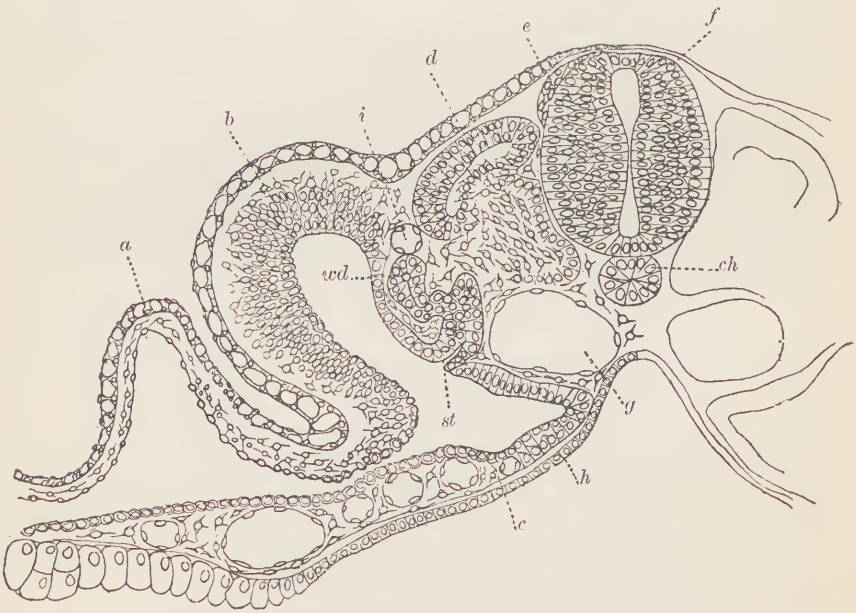


Fig. 102.—Transverse Section through Duck Embryo with about Twenty-four Primitive Segments. *a*, Amnion; *b*, somatopleure; *c*, splanchnopleure; *d*, muscle-plate; *e*, spinal ganglion; *f*, spinal cord; *g*, aorta; *h*, hypoblast, *i*, cardinal vein; *wd*, Wolffian ducts; *st*, segmental tube; *ch*, notochord. The proto-vertebra of older writers included the tissue between *d* and *g* in which vertebral elements are found, and through which nerve-roots pass. (Hertwig, from Balfour.)

another hollow projection, the *allantois.* The allantois forms a vesicular expansion which in birds and reptiles continues membranous and extends beneath the shell of the egg, carrying with it vessels which perform the respiratory function till the animal is hatched. In mammals it is elongated and divided by hour-glass contraction into an extra-embryonic and intra-embryonic dilatation separated by an elongated cord, the *urachus.* The intra-embryonic dilatation remains as the urinary bladder; the extra-embryonic part, projected at the umbilicus, retains for a while its cavity, but owes its importance to its mesoblastic layer being spread out in contact with the uterine wall, carrying with it bloodvessels from the embryo, and rapidly developing the foetal part of the placenta, which furnishes the means of intra-uterine respiration and nutrition.

Wolffian bodies and middle-plates. In the superficial groove between the paraxial and lateral mesoblast, when already the split for the coelom exists, but before the walls of the embryo are folded in, a cylinder of corpuscles which speedily becomes tubular makes its appearance, the *Wolffian duct*, connected with the *Wolffian body* or temporary renal organ discovered by the pioneer in embryology, C. F. Wolff (1759). This duct grows backwards with the embryo, and ultimately terminates where the allantois springs from the hind-gut. There is difference of opinion as to the source whence it is derived, whether mesoblastic or epiblastic, but it has been observed as a solid cord in conjunction with the epiblast in one section, while, in another further forward it was continuous with the mesoblast, and distinct from epiblast; and this condition has been shown to me by Mr. J. F. Gemmill. The epiblastic, therefore, is the prior connection. On the deep side of the Wolffian duct, the lateral mesoblast projects inwards so as to form with its neighbour of the opposite side, underneath the mesoblastic somites and notochord a mesial mass, *the middle plate* (Remak) or *intermediate cell-mass*; while, beneath this, the body-cavity projects inwards so as to separate the middle-plate by mesentery from the intestine.

In this middle-plate, besides the great vessels (which, according to His and Hertwig are mesenchymal), there are developed the primitive renal organs, occupying nearly the whole length of the embryo, and divided into three different organs with very different histories, viz., the head-kidneys or fore kidneys, the Wolffian bodies and the hind kidneys. In the formation of these organs, two independent sets of structures take part, besides the Wolffian duct, viz., glomeruli and tubules. The tubules, sometimes termed *segmental*, are transverse, arranged in correspondence with the primitive segments, and start from the body-cavity. The glomeruli are vascular arrangements of the same sort as the glomeruli of the adult kidney, and dip into expansions in the course of the tubules. Three or four of the foremost glomeruli dip into hollows or tubes communicating with the end of the Wolffian duct, and constitute the head-kidney or *pronephros*. The greater extent of the organ constitutes the Wolffian body or *mesonephros*, and shows at first a series of solid growths of the middle-plate, which become hollowed out by extension of tubular prolongations from the body-cavity, and ultimately open into the Wolffian duct after receiving the glomeruli in their course, the part of each tube between glomerulus and abdominal cavity disappearing. At first occupying the whole length of the visceral cavity, the Wolffian body retreats towards the groin, and disappears in embryonic life, leaving only minute vestiges in connection with ovary and testis. The hind kidney or *metanephros* is the permanent kidney of birds and mammals, and takes origin from the hinder part of the middle-plate, while the ureter is described as given off from the hinder end of the Wolffian duct; but the exact details of origin, both of kidney and ureter, are still involved in obscurity.

Müller's duct is the name given to a duct which in elasmobranch

fishes and amphibia is formed by longitudinal division of the Wolffian duct backwards from a point as far forward as the front of the Wolffian body; but in reptiles, birds, and mammals it makes its first appearance at a later date on the surface of the Wolffian body, as an open groove whose edges coming together convert it into a tube. Even in birds and mammals, however, it is in part of its course very intimately connected with the Wolffian duct. Müller's duct becomes in the female the oviduct, but in the male has a mere temporary development, while the epididymis and vas deferens of the male are formed from the Wolffian duct. The epithelial boundary of the body-cavity does not, over the surface of the Wolffian body, become flattened as it does elsewhere, but

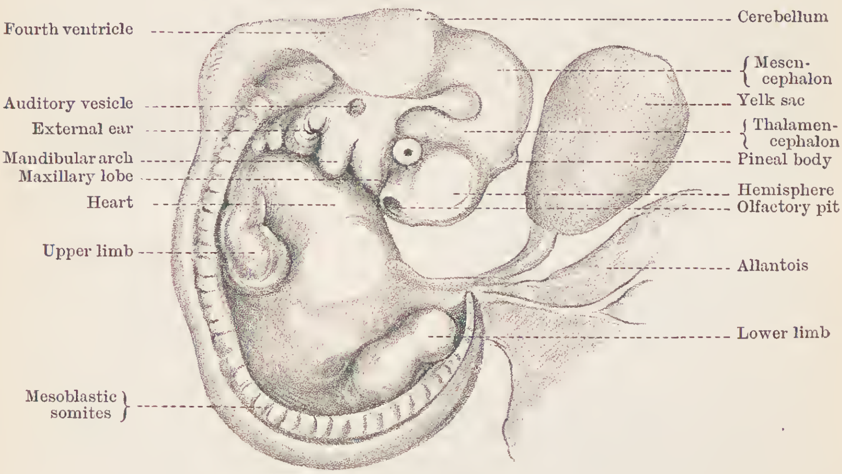


FIG. 103.—HUMAN EMBRYO, $\frac{6}{1}$ (adapted mostly from Fraser, partly from Allen Thomson).

is columnar or cubical, and is termed the *germinal epithelium*. It is from the part of the germinal epithelium on the outer border of the Wolffian body that Müller's duct is developed, while from the part on the inner border are developed the essential elements of the testicle in the male, and of the ovary in the female. (See *Development of Reproductive Organs.*)

The head and neck. The first cerebral vesicle is from its earliest development turned down into the fossa which separates it from the yelk; and as growth proceeds, the second vesicle lies over the extremity of the fore-gut, while the first vesicle is turned round so as to point backwards beneath it. The heart, when it appears, likewise forms a prominence on the ventral aspect of the fore-gut; and between this and the first cerebral vesicle is left a depression called the *stomodaeum*, where epiblast and hypoblast are in contact, and afterwards rupture to form the primitive mouth. In front of the place of rupture (*i.e.* proserial to it) the stomodaeal epiblast retains contact with the base of the brain, close behind the optic commissure, and is gradually shut off from the surface; while another

pouch projects from the brain, so as to lie ultimately behind the epiblastic pouch; and these two pouches together form the pituitary body.

The stomodaeum and the heart become separated, and a series of five arches of mesoblast, commencing as lateral thickenings and becoming completed in the middle line, make their appearance between. These are known as the *visceral or post-stomal arches*, and appear in pairs, the nearest to the head being first and largest, and completing before the others the arch by union of the right and left process. This first arch is called *mandibular*, and constitutes the part of the face in which the lower jaw appears. The second is the *hyoid*, and to it belong the body and small cornu of the hyoid bone. To the third belong the great cornua of the hyoid bone, while the fourth and fifth are, in birds and mammals, small and unimportant. Between the arches are the four *visceral clefts*, in which the mesoblast is absent, and the epiblast and hypoblast come in contact, partly by dipping in of the epiblast, but still more by lateral pouching of the hypoblast. In water-breathing animals, the communication of the pharynx with the integument is completed by rupture of these layers, and the slits so formed remain as gill slits. In some fishes the number of visceral arches is greater than five, while the mandibular is always the foremost. In the higher vertebrates the number of visceral arches is always five, and the clefts are unperforated; but a congenital fistula-like opening into the pharynx from behind the jaw occurs as a rare abnormality, and is to be accounted for by permanent perforation of the second, third, or fourth cleft. The first cleft forms from its hypoblastic part the Eustachian tube and tympanic cavity, and by the dorsal end of its epiblastic depression the external auditory meatus. In connection with the ear, there is already, at a date prior to the appearance of the visceral arches, another opening to be seen, the *auditory pit*, situated at the side of the third cerebral vesicle; it becomes shut off from the integument at a point opposite the base of the second visceral arch, and forms the *auditory vesicle* destined to be developed into the internal ear. So also the *olfactory pit* is an epiblastic depression on the under surface of the first cerebral vesicle, not to be confounded with the nostril; and the crystalline lens of the eyeball is formed from a similar invagination converted into a closed vesicle.

Dipping down in front of the first cerebral vesicle and the optic vesicles the *fronto-nasal process* is projected, which has on each side a lobe called *lateral nasal process*, and in front a pair of lobes called *middle nasal processes*, while a notch is left on each side between middle and lateral nasal processes for the nostril. The middle nasal processes unite to form the columella of the nose, the mesial groove of the lip, and, by a pair of *globular tubercles* at their extremity, the intermaxillary part of the palate; while at their united base the septum of the nose, with a free inferior margin, projects into the roof of the mouth. Both lateral and middle nasal processes are met at the side by another process, the *maxillary*

lobe, which comes forward below the eye, and not only forms the cheek and greater part of the upper lip, but sends inwards from its lower edge a lamina to meet, in the long run, both its neighbour of the opposite side and the septum of the nose, so forming the palate. Thus the nasal cavity takes origin altogether independently of the fore-gut, as do also the walls of the mouth, with the exception of the tongue. A communication from mouth to nose is left between the middle nasal and the maxillary lobe in ruminants and some other mammals, and leads in them into the supplementary organ of special sense called Jacobson's organ; while another such passage is left between the maxillary lobe and the lateral nasal process, and becomes the lachrymal duct.

The tongue appears first as a mesial eminence, *tuberculum impar*, opposite the first visceral cleft, separated by a furrow from a horse-shoe elevation opposite the succeeding arches, which is called the *furcula* and

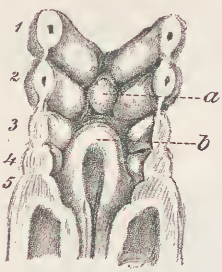


FIG. 104.—ANTERIOR WALL OF MOUTH AND PHARYNX of human embryo about $\frac{1}{12}$ inch long. *a*, Tuberculum impar; *b*, furcula. The visceral arches are numbered. (After His.)

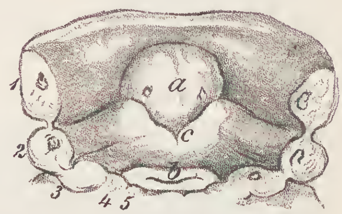


FIG. 105.—FLOOR OF MOUTH AND PHARYNX of human embryo $\frac{1}{2}$ inch long. *a*, Tuberculum impar; *b*, epiglottis; *c*, ductus thyreoglossus. (After His.)

is the rudiment of the epiglottis and aryteno-epiglottidean folds. The second and third visceral arches unite on each side, and intrude a narrow elevation between the tuberculum impar and furcula to form the root-part of the tongue behind the V-shaped mark, while a pit, *ductus thyreoglossus*, deepens down behind the tuberculum impar. The ductus thyreoglossus dilates at its deep extremity to form the mesial portion of the thyroid body, becomes obliterated in the middle, and at its entrance remains as the foramen caecum of the tongue. The thyroid body has, in addition to this mesial origin, two lateral origins from pouches of the fourth visceral clefts. The thymus is of similar nature to the thyroid, taking origin, in mammals, principally, if not altogether, from pouching of the third clefts; in birds, from pouching of the third and fourth; and in reptiles, from the second, third and fourth clefts.

The limbs. The limbs make their first appearance in the chick in the third day, and in the human embryo during the third or fourth week. On each side beyond the outer margins of the muscle-plates, there is a line or ridge beyond which the mesoblast becomes thinner as it is followed

in a ventral direction; and on this line the limbs appear as two lobes with dorsal and ventral surfaces, their edges directed towards the cephalic and caudal ends of the embryo. The division into digits is soon indicated by four depressions, the thumb and great toe being the digits nearest the head. The hand and foot are both at first sessile, the elongated part of the limb being later of making its appearance. I would further observe that the elbow is from the first directed away from the head, while the knee is primarily directed outwards and acquires its later position by the rotation which turns the sole of the foot towards the ground.[1]

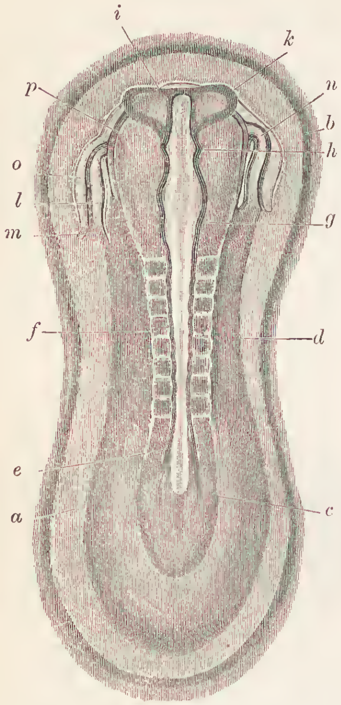


FIG. 106.—EMBRYO RABBIT OF 8 DAYS AND 14 HOURS, $\frac{21}{1}$. *a*, Area pellucida; *b*, anterior bounding fold; *c*, axial zone; *d*, peripheral zone; *e*, medullary fold; *f*, mesoblastic somites; *g*, *h* and *i*, hinder, mid and fore brain; *k*, primary optic vesicle; *l*, ventricle of heart; *m*, vena omphalomesenterica; *n*, aortic extremity of heart; *o*, parietal space around the heart; *p*, wall of throat dimly visible. (Kölliker.)

Commencement of vascular system. In birds and mammals, as shown by Kölliker, the earliest condition of the heart is in the form of two symmetrically placed tubes at the sides of the head, already begun in the rabbit to appear while yet there are only two mesoblastic somites developed. These primitive hearts lie in the deeper layer of the mesoblast of the lateral zone, their hinder ends diverging into the area pellucida. By the folding of the layers of the embryo, they soon meet together on the ventral aspect of the fore-gut to form a single tube, which was long supposed to be the primitive condition, and actually is so in elasmobranch

[1] Although, in elasmobranch fishes, Balfour has shown that muscle-plates are prolonged into the origin of the pectoral fin, it can scarcely be considered as ascertained that the proper limb-muscles are derived from them; and, according to Paterson, the limbs of birds and mammals receive no prolongations from the muscle-plates. Adult anatomy tells us that the nerves of the limbs are derived from ventral divisions, and that, while, in the upper limbs, they come from five spinal nerves, they assuredly belong to a larger number in the lower limbs. The skeleton of the limb (clavicle excepted) probably always starts from the base of the free part, and extends from this outwards into the free part, and dorsally and ventrally within the wall of the trunk to form the limb-girdle. These various considerations, together with the want of correspondence of mesial fin-rays of fishes with vertebral segments, are sufficient of themselves to excite suspicion that the doctrine that the limbs are developments belonging to special segments of the trunk is without just foundation.

fishes and amphibians. By the formation of bloodvessels in the area opaca and area pellucida, outside the embryo proper, and of others within the embryo, continuous with the anterior end of the cardiac tube, a circulatory system is completed. The area vasculosa is bounded peripherally by a *sinus* or *vena termianlis*, whence the blood returns by a right and left vitelline vein, and reaches by the heart the *truncus arteriosus*. Thence the blood is conveyed by a series of *right* and *left branchial arches* round the fore-gut to fall into a pair of *primitive aortae* which afterwards unite; while lateral branches, the *vitelline arteries*, a single pair in the chick, but numerous and slender in the mammal, carry the blood back to the area vasculosa. The branchial arches are five in number, the foremost being first to appear; but in birds and mammals they do not all exist at the same time. The two lateral divisions of the coelom turn round to the middle line along with the right and left

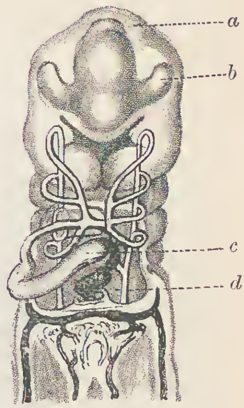


Fig. 107. — Frontal Reconstruction from embryo shown in Fig. 101. *a*, Mesencephalon; *b*, primary optic vesicle; *c* and *d*, ventricle and auricle of heart. (After His.)

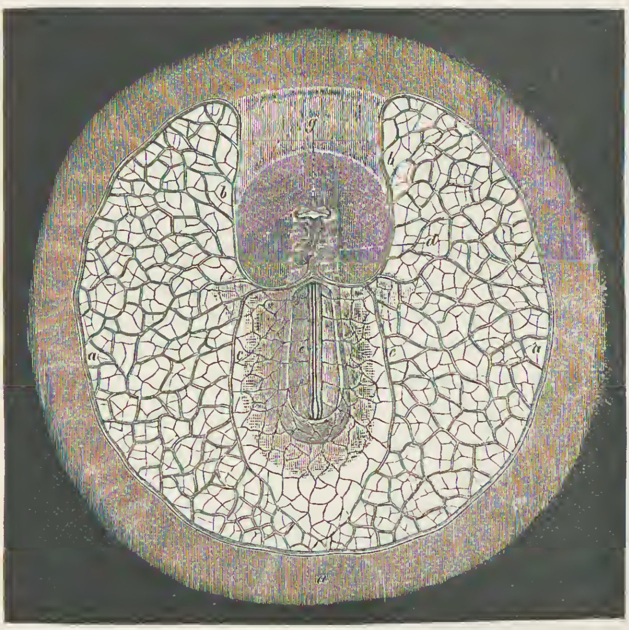


Fig. 108.—Embryo Rabbit with its Area Vasculosa, ventral aspect. *a*, Sinus terminalis; *b* and *c*, anterior and posterior roots of omphalomesenteric veins; *d*, heart; *e*, primitive aortae; *f*, *f*, omphalomesenteric arteries; *g*, first cerebral and primitive optic vesicles. (Kölliker, after Bischoff.)

tubular hearts, and when the mesial heart is formed, meet in a ventral

mesocardium which soon disappears. At the same time they push in between the heart and fore-gut so as to make a dorsal mesocardium which persists. The venous end of the tubular heart becomes bent with a ventral convexity, by the arterial end receding from the head and the venous end being tucked up towards the dorsum to assume the position of the auricles into which it is developed, while the projecting convexity becomes the apex. The veins, in their change of position, carry with them the wall of the coelom, and principally by this means the pericardium is cut off as a separate sac.

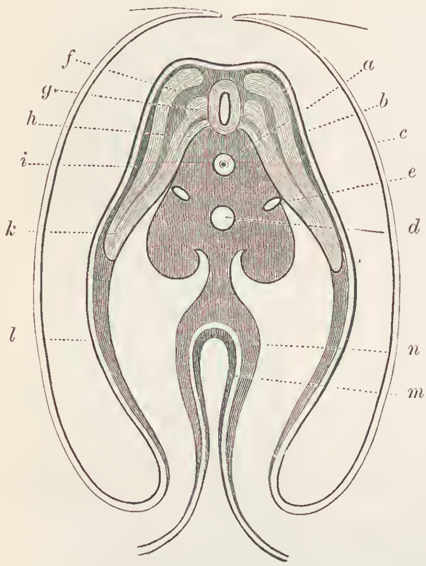


Fig. 109.—Transverse Section through Embryo Chick Five Days Old, and the Amnion around it. *a*, Sheath of notochord; *b*, epidermis; *c*, amnion nearly closed; *d*, single aorta; *e*, cardinal veins; *f*, muscle-plate; *g*, spinal ganglion; *h*, anterior nerve-root; *i*, cutaneous layer; *k*, the segmented structures pushing forward into *l*, the primitive abdominal wall; *m*, the glandular, and *n*, the musculo-intestinal layer, together forming the splanchnopleure. (Kölliker, after Remak.)

While the heart and vitelline vessels belong to the splanchnopleure, the intercostal and lumbar arteries pass out in the somatopleure, and, in the transparent part beyond the limb-ridge, the *membrana reuniens inferior*, are continued into a remarkable network of vessels, very accurately represented by Kölliker.

The surroundings of the embryo. The somatopleure and splanchnopleure continue separated by the body-cavity beyond the embryo, passing quite round the yelk, and in fishes and amphibians they continue in contact all the way. But in reptiles and birds and mammals, the extra-embryonic somatopleure quits the spanchnopleure and rises up over the dorsum of the embryo, so as to form a pouch with an orifice which contracts and disappears, inclosing the embryo in a transparent sac, the *amnion*. The part of the somatopleure beyond the amnion is called the *false amnion*, and remains adherent by its epiblastic surface to the much thinned and disappearing zona pellucida, called also *prochorion*, which in turn adheres to the uterus. There is thus an extra-embryonic extension of the coelom between the false amnion and the continuation of the splanchnopleure round the yelk, and it is into this space that the allantois extends. The false amnion, with the prochorion, forms an envelope, the *chorion*, from which there soon project multitudes of branching villi embedding themselves in the mucous membrane of the uterus.

The mucous membrane of the uterus undergoes a marked increase of

growth, and becomes in the human subject, and most other mammals, the seat of a great thickening destined to be removed with the foetal membranes in parturition, and therefore named *decidua.* The part lining the cavity of the uterus is called *decidua vera.* But the ovum becomes embedded by the part immediately surrounding it rising up and forming a continuous covering, the *decidua reflexa,* which separates it from the free surface of the decidua vera, while the part to which the ovum is originally adherent is that to which the placenta is afterwards attached and is distinguished as *decidua serotina.* The decidua consists of all but the deepest part of the uterine mucous membrane hypertrophied and altered, involving the tubular glands and presenting a structure containing blood-vessels and largely composed of cells of epithelial character. The villi of the chorion were supposed to pass into the mouths of the glands, but were shown by Turner to hollow for themselves new depressions between

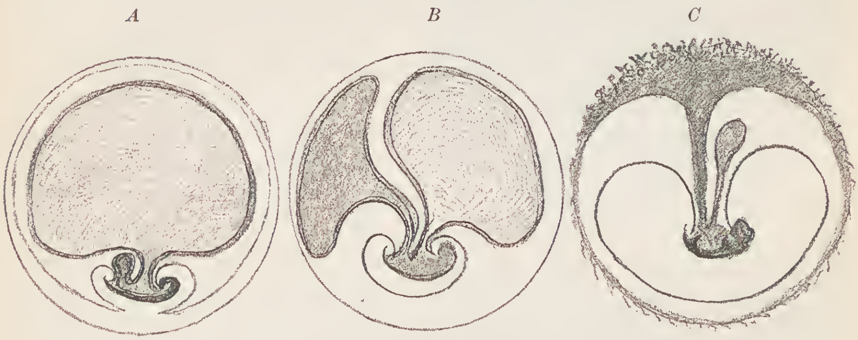


Fig. 110.—Diagrams of Structures outside the Embryo. The outer circle represents the chorion. *A*, The amniotic sac, not yet complete, is continuous with the false amnion which lines the chorion; the yelk sac is large, and the allantois only a small vesicle; *B*, amnion complete, allantois spreading in contact with chorion; *C*, amniotic sac enlarged, the yelk sac persisting as a relatively small umbilical vesicle, and the placenta formed from the outer layer of the allantois with the chorion.

them. The columnar ciliated epithelium gives place to flattened cells, and the growth of the decidua goes on till the fifth month. The decidua vera exhibits two layers: one, a *compact* layer nearer the surface, in which the interglandular elements especially have increased, while the necks of the glands take a straight course between; and the other, a *spongy* layer with less interglandular substance, in which the deeper parts of the glands are swollen out and contorted so as to give a lacunar structure. The decidua reflexa, being formed by folding, has compact substance with orifices of glands directed to both its surfaces, and spongy substance in the middle. The decidua serotina has likewise compact and spongy substance, and it is from the compact substance that the placenta is formed, while the spongy substance is the site of the separation of the placenta in parturition.

The placenta consists of two parts, the maternal and the foetal, which are inseparably interlocked. But it is interesting to note that in ruminants they remain distinct, the uterus presenting a number of permanent or button-like elevations, *cotyledons,* over which the chorion develops masses

of villi corresponding to them and fitting deeply into them; and these foetal tufts can be pulled separate from their maternal cotyledons, while a considerable amount of milky-looking substance can at the same time be squeezed from the recesses which they have occupied.

The foetal placenta is developed from the allantois. In ruminants the sac of the allantois expands so as to fill the cornu of the uterus for a while, till the amnion expands and casts it to one side, where it can be seen shaped like a sausage, as the name implies. But in the human subject the sac only touches the uterine wall, while the outer layer, the mesoblastic or mesenchymal covering, is continued as a delicate web conveying vessels for a time to the whole extent of the chorion, and entering its villi. In the decidua serotina the villi of the chorion are exaggerated (*chorion frondosum*), and the compact layer of decidua loses all trace of glandular structure, while the interglandular substance is developed into blood-sinuses surrounding the villi, and into a *basal layer* of firm tissue containing large multinucleated corpuscles. The basal layer passes out in the form of *septa* between the groups of villi, uniting them in cotyledons, and is prolonged round the sinuses as a thin *subchorial* layer (Kölliker), so as to grasp the bases of the foetal tufts. The tufts of foetal bloodvessels are most intimately connected with the blood-sinuses which surround them, but are nevertheless covered by flattened epithelium. Tortuous arterioles pass through the basal layer to dilate at once into the maternal sinuses, whence the blood returns by veins, there being no capillaries anywhere intervening. The mode of development of the blood-sinuses affords matter of dispute as to whether they are truly maternal or clefts between the foetal and maternal structure. Hubrecht and other recent writers, observing in different animals large epiblastic developments at an early stage, support the theory of clefts put forward by Kölliker and others; but it is questionable if anything has been seen to upset the view that the deciduate placenta of the human subject is fundamentally comparable with the indeciduate placenta of ruminants, and that the epithelium of the foetal tufts of the human placenta is representative of both the foetal and maternal epithelia in those animals.

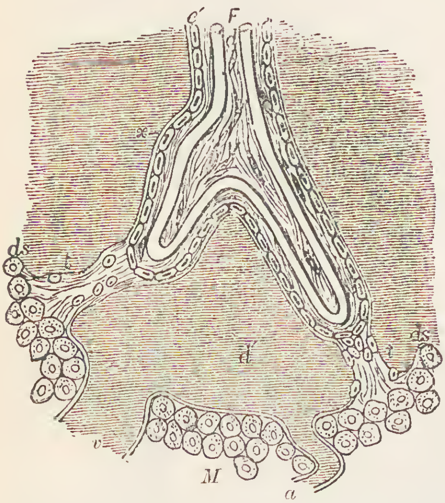


FIG. 111.—*F*, Foetal placenta; *M*, maternal placenta; *a*, tortuous artery; *v*, vein returning blood from maternal sinus *d′*; *d*, loop of vessel of foetal villus; *e′*, uterine epithelium; *x*, wall of maternal sinus lined with endothelium; *t*, band stretching across from sinus to surface of villus; *ds*, decidua serotina. (Hertwig, from Turner.)

SYSTEMATIC ANATOMY.

THE SKELETON.

THE whole osseous and cartilaginous framework of the body constitutes what is known as the skeleton.[1]

The skeleton may be conveniently considered as consisting of two parts, the *axial* or central, and the *appendicular* or that pertaining to the limbs. Each limb starts from an arch or girdle situated in the trunk; the upper limb being supported by the scapula and clavicle, which are easily separable from the structures on which they rest, and the lower limb by the os innominatum or pelvic bone, which enters largely into the boundary of the lower part of the trunk, and is closely united to the vertebral column. The expression 'axial skeleton' excludes these girdles, which in their essential constitution belong altogether to the limbs, and refers to the skull, vertebral column, ribs, sternum and costal cartilages, parts which lie in a longitudinal range, and exhibit a segmental repetition of parts. The skull, however, is so complex that its consideration may be delayed till after the limbs are examined.

I. THE AXIAL SKELETON OF THE TRUNK.

THE VERTEBRAL COLUMN.

The vertebral column extends from beneath the skull the whole length of the body, and consists of a series of bones called *vertebrae*, fundamentally homologous, but differing greatly in detail. It forms a column of support by means of a series of solid structures, the *bodies* of the vertebrae. From the bodies spring the *neural arches*, which extend backwards and bound

[1] The junior student before proceeding to the study of individual bones and joints, ought first to acquaint himself with the general characters of bone, described at page 24, and with the nature, varieties, and movements of articulations explained in the account at page 36. It may also be noted that although most of the details of bones are best studied on dried specimens, the articular surfaces are seen to most advantage in the recent state, covered with fresh articular cartilage.

Fig. 112.—Vertebral Column with its ligaments dried; view from front and right side.

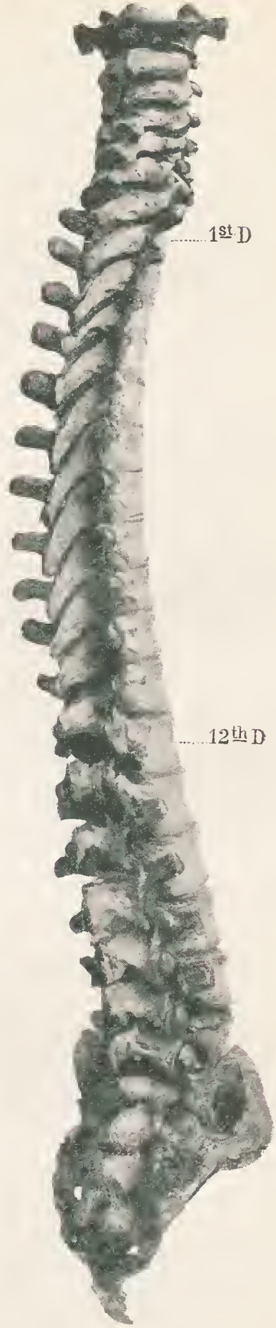


Fig. 113.—Vertebral Column; view from behind and right side.

the *neural canal*, inclosing the spinal cord and roots of spinal nerves; while, in front of the column is the visceral cavity completely encircled in the upper part of the thorax by *costal arches*, into whose formation there enter vertebrae, ribs, costal cartilages and sternum. But the ribs developed in the thorax as separate bones are represented more or less distinctly in other regions by comparatively minute parts, which are incorporated in the structure of the vertebrae.

Five vertebrae are united to form a bone called the *sacrum*, to which the pelvic bones are attached; and beyond the sacrum there are four dwindled vertebrae which tend in the adult to become fused together, and are known as the *coccyx*. Between the skull and the sacrum there are twenty-four vertebrae which remain distinct throughout life. There are thus thirty-three vertebrae in all.

Of the twenty-four *distinct* or *movable* vertebrae, twelve have ribs articulating with them and are called *thoracic* or *dorsal*, seven intervene between the thoracic vertebrae and the skull and are called *cervical*, while the remaining five, placed below the thoracic, are called *lumbar*. The thorax begins with the first of the vertebrae bearing ribs so prolonged as, with the aid of costal cartilages and sternum, to complete a circle or *costal arch*. The cervical vertebrae have rudimentary ribs or *costal elements* incorporated with them, and the seventh has in exceptional instances a pair articulating with it. But even in animals such as the crocodile, in which the vertebrae immediately behind the skull are provided with separable ribs, the name cervical is given to as many as intervene between the skull and the first vertebra bearing a complete costal arch. The first and second cervical vertebrae are considerably modified in connection with the movements of the head, and are called respectively *atlas* and *axis*.

The vertebrae, with some exceptions at the extremities of the series, consist of three main elements which remain separate for some time after birth; namely, a solid mesial portion, the *centrum*, and two lateral parts which approach one another behind and are afterwards united to complete the *neural arch*, termed sometimes simply the *arch*. During childhood, the centrum and the bases of the arch become united into one solid mass, afterwards completed by a thin plate above and below, and the block so constituted is the *body*. Thus, though it is customary to speak of a vertebra as consisting of a body and an arch with processes, the body has entering into its composition two lateral elements or non-central parts allied in origin much more closely to the arch than to the centrum.

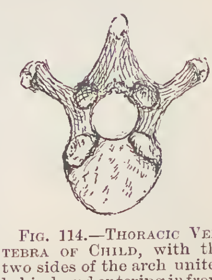


Fig. 114.—Thoracic Vertebra of Child, with the two sides of the arch united behind, and entering in front along with the centrum into the construction of the body.

The body of a vertebra presents, for attachment of the intervertebral discs which separate it from the bodies of the vertebrae above and below, an upper and an under fine-grained surface of dense tissue, thicker towards

the circumference, and deficient or membranous toward the centre. Anteriorly the body is slightly grooved transversely so as to make the upper and lower margins prominent, and in the thoracic and lumbar regions it is projected well forwards in front of the arch. Posteriorly it is slightly grooved vertically and presents two foramina placed side by side or opening into a common depression, which give exit to veins.

The aperture bounded by the neural arch and the body enters into the formation of the spinal canal which contains the spinal cord and the roots of the spinal nerves, and it is called the *ring*. From the arch the *spinous process* or *spine* projects in the mesial plane, while the *transverse processes* project laterally. The parts of the arch intervening between the body and the transverse processes are called the *pedicles*, and the parts between the transverse processes and the spine are the *laminae*. The pedicles have their upper margins on a level with the upper surface of the centrum, while the centrum descends further than their lower margins. In fact, in all vertebrata the arch corresponds with the proserial and never with the retroserial half of the centrum. The laminae at their upper margin have a roughness looking backwards, and at their lower margin a roughness looking forwards, marking the attachments of the ligamenta subflava. Projecting upwards and downwards, close to the transverse processes, are the *superior* and *inferior articular processes*, carrying articular surfaces, by means of which one vertebra has synovial articulation with another. Above and below the pedicles are the *superior* and *inferior notches*; and when the vertebrae are articulated, apertures are left between the inferior notches of one vertebra and the superior notches of the next, and completed in front by the intervertebral disc. These are the *intervertebral foramina*, and give passage to the spinal nerves.

Fig. 115.—Fourth Thoracic Vertebra. *a*, Surface for lower facet of head of fourth rib; *b*, for tubercle of fourth rib; *c*, for upper facet of head of fifth rib.

It is important to note that the transverse processes in the cervical, thoracic and lumbar regions are not perfectly homologous structures.

The thoracic vertebrae, twelve in number, are specially characterized by the presence of articular surfaces for ribs. The bodies are flat above and below, in the middle of the series they measure from behind forwards as much as transversely, and, except in the first and the three last, they present on the non-central part on each side a small articular facet at the upper margin for articulating with the head of the corresponding rib, and another at the lower margin for the head of the rib below. The ring is small and circular. The spines are elongated, sloping down-

wards one over another in the middle of the series, ending in a blunt point, and springing gradually from the laminae, whose upper borders unite to form a mesial ridge separating a right from a left side, while a third is left inferiorly. The transverse processes are cylindrical, inclined to a marked degree backwards, and swollen at the extremity, in front of which, except on the eleventh and twelfth, there is an articular surface looking forwards and upwards for the tubercle of the corresponding rib. The transverse processes decrease regularly in length from the first to the last, in which they are represented by three tubercles slightly connected by a short neck which may be almost absent, and these tubercles are homologous with three projections on the swollen ends of the typical thoracic transverse processes. One of these projections, external, is a ridge for the posterior costo-transverse ligament; a second, internal, gives attachment to the semispinalis and multifidus spinae muscles; while the third, inferior, gives attachment to the inner insertions of the longissimus dorsi muscle. The inferior notches are deep, the superior shallow and due altogether to the superior articular processes striking up behind them. The articular processes project in directions continuous with the margins of the laminae, the superior rising above the level of the rest of the vertebra, while the inferior are mere lateral expansions of the laminae. The articular surfaces are almost vertical, the superior looking backwards and outwards, the inferior forwards and inwards, and both lying in the arc of a circle whose centre is at the front of the body, an arrangement favourable for rotation.

Special characters of certain thoracic vertebrae. The *first* has the upper of the two pairs of costal surfaces on its body placed some distance down

FIG. 116.—FIRST THORACIC VERTEBRA from above. *a*, Facet for head of first rib; *b*, for tubercle of first rib; *c*, for upper part of head of second rib.

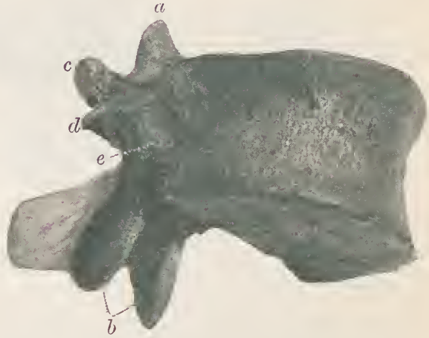


FIG. 117.—TWELFTH THORACIC VERTEBRA. *a*, *b*, Superior and inferior articular processes; *c*, *d*, internal and inferior tubercles of transverse process (corresponding with mammillary, and accessory processes of a lumbar vertebra); *e*, costal facet elevated above into an outer tubercle of the transverse process.

and shaped to receive the whole head of the first rib; also the non-central parts of its body project upwards after the fashion of a cervical vertebra, deepening the superior notches. The *tenth*, *eleventh* and *twelfth* articulate

each with only one pair of ribs; the tenth bearing one pair of articular surfaces on its body and another on its transverse processes, while the *eleventh* and *twelfth* have no surfaces on their transverse processes, and the twelfth has its one pair placed well back on the pedicles. Still more distinctive of the twelfth is the eversion of the surfaces of its inferior articular processes, and the separation of the three tubercles which together represent the transverse process of the typical thoracic vertebra.

The lumbar vertebrae, five in number, are massive; their bodies have the transverse diameter greater than the mesial; their rings are three-sided and large. The spines are horizontal and spring abruptly from the laminae; they are laterally compressed, nearly as deep as long, and end in a linear extremity. The transverse processes have only a slightly backward inclination. They are compressed from before backward and elongated, evidently in series with the ribs. The laminae are nearly horizontal, and the articular processes stand out distinctly from them, the superior further separate than the inferior, and embracing those of the vertebra above. The superior articular surfaces are transversly concave, looking partly backwards and partly inwards, the two parts meeting rather abruptly, while the inferior articular surfaces have a corresponding convexity looking forwards and outwards. Projecting backwards from the superior articular processes are two tubercles called *mammillary processes*, in series with the inner angles of the extremities of the thoracic transverse processes and giving attachment to origins of the multifidus spinae. They correspond with the *anapophyses* (Owen) largely developed in the hedgehog and still more prolonged in the armadillo to support its armour. At the bases of the transverse processes posteriorly, and pointing downwards, are a pair of pointed projections, sometimes indicated by little more than roughness; they are called *accessory processes*, give attachment to insertions of the longissimus dorsi, and are in series with the inferior angles of the extremities of the dorsal transverse processes. They are

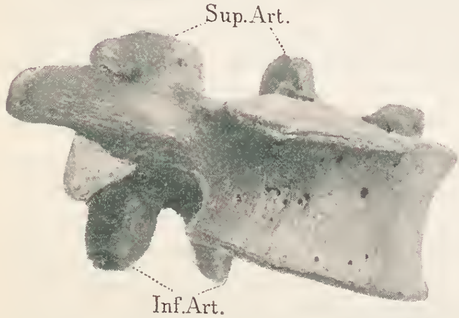


Fig. 118.—Second Lumbar Vertebra. The superior and inferior epiphyses of the body can still be distinguished.

Fig. 119.—Fifth Lumbar Vertebra from behind. Note the wide separation of the right and left articular processes, the decrease in depth of the body behind, and the irregular shape of the transverse and spinous processes.

seen in perfection in monkeys, carnivora and other animals, as spikes projecting over the following vertebra so as to lock the two vertebrae together. They are the *metapophyses* of Owen.

The fifth lumbar vertebra has the body very distinctly deeper in front than behind, its transverse and spinous processes more massive and less shapely than those of the other four, its inferior articular processes wide apart, and in connection with this, the inferior margins of its laminae thrown backwards and outwards.

The cervical vertebrae are seven in number, but the first two, the atlas and axis, will require separate description. All possess as a distinctive character a pair of foramina in connection with the transverse processes. These are often named *arterio-vertebral*, the six upper of them being usually threaded by the vertebral artery. But the seventh is never so occupied, and as the bars which complete the foramina in front are in series with

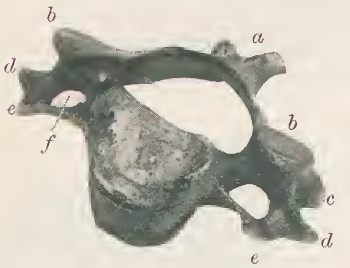


FIG. 120.—THIRD CERVICAL VERTEBRA. *a*, Spine; *b*, *b*, superior articular processes; *c*, left inferior articular process; *d*, *d*, posterior tubercles of transverse processes; *e*, *e*, their anterior or costal tubercles; *f*, right costo-vertebral foramen.

FIG. 121.—SEVENTH CERVICAL VERTEBRA. *a*, Spine; *b*, *b*, superior articular processes; *c*, *c*, costo-vertebral foramina.

necks of ribs in the thorax, it is better to distinguish them as *costo-vertebral.* The costal nature of the bars in question is made manifest by their springing from the side of the body, in front of the pedicle, and by the seventh cervical vertebra not only having a separate centre of ossification in each, but showing in childhood the exact extent of the costal part marked off by deep lines of separation, where the head of the rib meets the body of the vertebra and where its tubercle meets the transverse process. Outside the foramen the union of the two bars is effected by a thin bridge near their lower margins, on a level with the superior notch, so that the transverse process presents a groove superiorly for the emerging nerve, and at its extremity an anterior and a posterior tubercle. The bodies increase in size from the top of the series to the seventh; they have a greater diameter from side to side than from before backwards, and their upper surfaces are bevelled at the anterior edge, while laterally the non-central parts rise up on each side above the centrum, making the body concave from side to side, and the superior notch as deep as the inferior. Conversely, the under surface of the body is convex from side to side, while in the middle it dips in front over the

body of the vertebra following. The ring is large and triangular. The laminae have oblique surfaces, and meet by their upper margins to form spines and again diverge. Thus the spines are bifid, and grooved on their under surface. The articular surfaces look, the upper pairs upwards and backwards, the lower pairs downwards and forwards, and so oblique is their inclination that when in position the articular processes on which they are placed form together two considerable pillars supplementing the bodies in the support of the head. From the third to the seventh the cervical vertebrae increase regularly in all dimensions, including length of spine and width between the extremities of their transverse processes.

The seventh cervical vertebra has the spine ending in a subcutaneous tubercle like the succeeding vertebrae, and is named on that account *vertebra prominens.* The posterior tubercle of its transverse process is more prominent than the anterior, and the inferior surface of the body is not prolonged downwards in front.

The atlas and axis owe their most striking peculiarities to the circumstance that in process of development the centrum of the atlas is

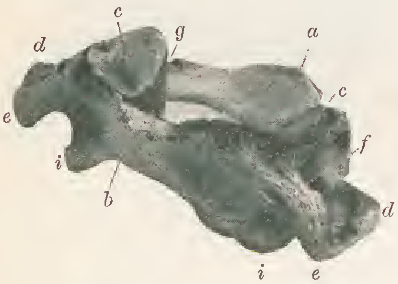


Fig. 122.—Atlas. *a*, Posterior tubercle; *b*, anterior tubercle; *c*, *c*, superior articular surfaces; *d*, *d*, tips of the vertebral parts of the transverse processes; *e*, *e*, tips of the costal parts of the transverse processes; *f*, upper orifice of left arterio-vertebral foramen; *g*, groove (only partially seen), on which bay the vertebral artery and suboccipital nerve—*i*, *i*, are placed outside the outer edges of the inferior articular surfaces.

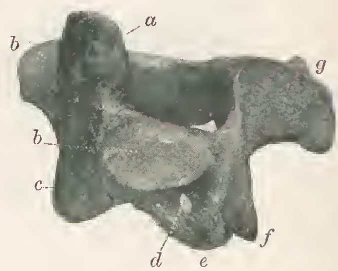


Fig. 123.—Axis. *a*, Odontoid process; *b*, *b*, superior articular surfaces; *c*, centrum; *d*, arterio-vertebral foramen; *e*, tip of transverse process; *f*, inferior articular process; *g*, strongly bifid spinous process.

modified in shape, separated from the rest of that bone, and united to the centrum of the axis, forming what is called its odontoid process, while the ventral extremities of the arch of the atlas become united by a centre of ossification which forms a bar gliding on the front of the odontoid process.[1]

The atlas incloses within an *anterior* and a *posterior arch* a large ring, the fore part of which is smaller than the hinder, and separated from it in the recent state by a transverse ligament extending between two lateral masses so as to lie behind the odontoid process of the axis and form the posterior part of a circle for its reception. On the back of the anterior

[1] It is remarkable that this arrangement exists not only in mammals, but in reptiles and birds, though it is generally admitted that mammals are not descended from either.

arch is a surface covered with cartilage for articulation with the odontoid process, and in front of it is a slight prominence, the *anterior tubercle*, so called in opposition to the *posterior tubercle*, which represents the spinous process. The *lateral masses* are two solid blocks which present on their upper surfaces a pair of superior articular surfaces for articulation with the condyles of the occipital bone. These surfaces are elongated and concave, with their posterior extremities opposite the widest part of the ring and their anterior extremities nearer one to the other, their outer margins elevated and their inner margins depressed and indented; while internal to each is a roughness marking the attachment of the transverse ligament. Beneath the lateral masses are two inferior articular surfaces, flat, circular, and looking downwards and a little inwards. Outside the lateral masses are the transverse processes, perforated by an arterio-vertebral foramen, like the other cervical vertebrae, but having only one extremity, which strikes out so far that the width between it and its fellow is not equalled by any succeeding vertebra till the first thoracic is reached. The bars uniting to form the posterior arch are cylindrical

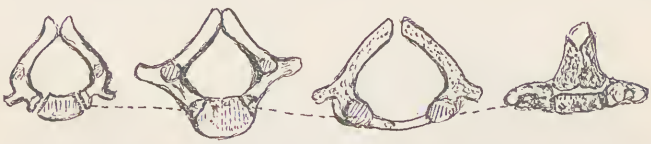


FIG. 124.—FOUR VERTEBRAE OF A CHILD AT BIRTH. *a*, Cervical; *b*, thoracic; *c*, atlas; *d*, axis. The dotted lines show the parts of the atlas and axis which correspond with the non-central part of the body in a dorsal and a typical cervical vertebra.

except immediately behind the lateral masses, where they are flattened superiorly, there being on each side a broad transverse groove overhung in front by the back of the superior articular surface. This is occupied by the vertebral artery as it winds round from the arterio-vertebral foramen before entering the skull by the foramen magnum; and the occipital or first spinal nerve emerges by it. It is really the superior notch, while the part which goes to form the lateral mass corresponds with the non-central portion of the body in other vertebrae. The groove is sometimes arched over and converted into a foramen. The ridge behind it corresponds in position with the superior articular process of a typical vertebra, and sometimes in old subjects the occipital bone rubs so much on the posterior arch as to form a sort of articular surface. The laminae of the atlas not unfrequently fail to meet in the middle line behind.[1]

[1] The atlas is occasionally subject to larger defects, both in the anterior and posterior arches. Especially worthy of notice is the occurrence of incomplete posterior arch in conjunction with enlarged ring and throwing forward of the transverse processes. It may be also here noted that by following the series of anterior and posterior intertransverse muscles till, by means of the rectus capitis anticus minor and rectus capitis lateralis, they respectively reach the skull, it can be shown that

The *axis* has its body surmounted laterally by superior articular surfaces homologous with the articular surfaces of the atlas, and in the middle by the *odontoid process.* The superior articular surfaces look upwards and outwards, but are slightly raised in their transverse diameter, so as to leave gaps in front and behind between them and the opposed surfaces of the atlas. The odontoid process is a pillar with a slightly constricted neck, smooth behind where it glides on the transverse ligament of the atlas, and with an oval surface in front reaching nearly to the summit for articulation with the atlas. Its summit is rough and presents two lateral slopes which give attachment to the check ligaments. The under surface of the body of the axis, the inferior notches and the inferior articular processes, are similar to those of the succeeding vertebrae. The laminae are continued into a deeply bifid spine, much stronger and also larger than those immediately succeeding it, and giving attachment to muscles both above and below it. The transverse process is short, and has only one tip.

The sacrum consists of five vertebrae united together, not only by their bodies, laminae and articular processes, but also outside the intervertebral

Fig. 125

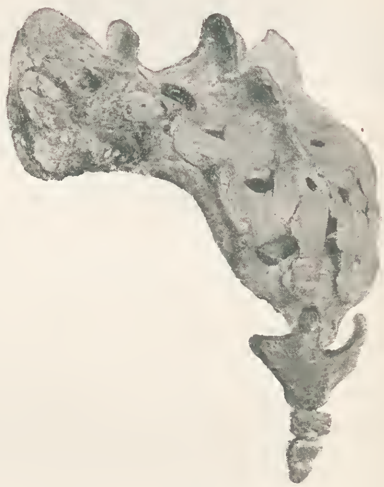


Fig. 126.

Fig. 125.—Sacrum and Coccyx, front view. The sacrum is turned sufficiently to one side to show the right auricular surface descending as far as the middle of the third sacral vertebra, and behind it, in shade, the surface of attachment of the dorsal sacro-iliae ligament. The epiphysis of the auricular surface, and that over the body of the first vertebra, are not yet completely united to the main bone.

Fig. 126.—Sacrum and Coccyx. View from behind and from the left side.

foramina, which consequently are converted into bifurcating canals opening

the tips of the transverse processes of the atlas and axis are in series with the posterior tubercles of those of the vertebrae following, while the anterior tubercles or tips of ribs are represented by mere roughness at the roots of the transverse processes (Allen, *Journal of Anatomy and Physiology*, xiv., p. 18).

by *anterior* and *posterior sacral foramina*, bounded externally by a solid block, the *lateral mass.* The sacral vertebrae diminish rapidly, from the first, which is the most massive in the column, to the fifth, which is rudimentary; and thus they constitute a wedge-shaped bone, the base of which articulates with the last lumbar vertebra by a body and articular processes, and is continued laterally into an expansion curving over to the ventral surface.

The ventral surface forms the back of the pelvis, and is concave from base to apex and slightly so from side to side. Mesially it is separated from the base by an acute angle, and projects forwards into the pelvic cavity, forming the *sacral promontory.* Below this, a series of four transverse linear elevations indicate permanently the borders of the five bodies of vertebrae, and extend to the abrupt internal margins of the anterior sacral foramina, whose external margins slope outwards in the form of deep grooves corresponding with the courses of the anterior divisions of sacral nerves.

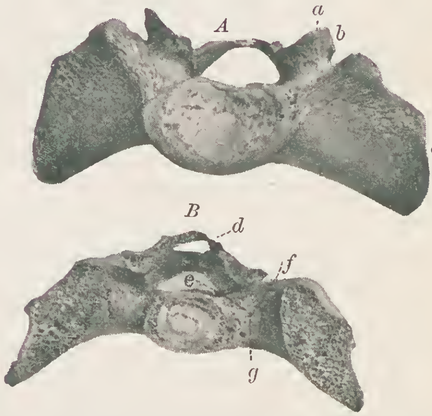


Fig. 127.—First and Second Sacral Vertebrae sawn separate, seen from above. A, Base of sacrum: *a*, articular process; *b*, transverse process; *c*, lateral mass. B, Second sacral vertebra: *d*, portion of arch of first vertebra sawn away with the second; *e*, *f* and *g* have the lines proceeding from them lying respectively in the intervertebral, the posterior and the anterior sacral foramen, showing how the intervertebral foramen is bifurcated by the union of the lateral masses of succeeding vertebrae.

The dorsal surface is convex both longitudinally and transversely. It presents in the middle line a series of spines, usually three or four in number; while inferiorly the laminae of the fifth vertebra, or of the fourth and fifth, failing to meet, leave the lower end of the *sacral canal* imperfect behind. Sometimes the laminae of the third and second vertebra have the like imperfection, and in rare instances the sacral canal is open in its whole length, without a single spine over it. Separated from the middle line by the series of united laminae are two rows of tubercles in series with the well-developed mammillary processes of the first sacral vertebra, and external to these are the *posterior sacral foramina*, smaller than the anterior, and giving passage to the posterior divisions of sacral nerves. External to the posterior sacral foramina is an outer line of ridges representing the tips of transverse processes, and separating the dorsal from the lateral surfaces.

The lateral surfaces belong to costal elements additional to transverse processes, absent from lumbar vertebrae, and exhibited in childhood in the three upper sacral vertebrae by additional centres of ossification. To this addition is due the stoutness of the lateral masses. On the

lateral aspect, towards the base, is the *auricular surface*, a large articular surface covered with cartilage for articulating with the iliac portion of the pelvic bone, but differing from the generality of articular surfaces in being more uneven. It extends over the first two vertebrae and a certain way over the third. Its ventral margin keeps close to the ventral surface of the bone, while the ear-shape from which it is named is due to the part on the first vertebra extending dorsally considerably further than the rest. The space between the auricular surface and the tips of transverse processes is occupied with fat, while the range of processes gives attachment to the strong posterior sacro-iliac ligament.

FIG. 128.—BASE OF SACRUM OF INFANT. *c*, Centrum; *m*, mammillary process; *t*, tip of true transverse process; *l*, main part of lateral mass, the costal element.

The fifth sacral vertebra has the free processes which form its imperfect arch turned downwards like inferior articular processes. They are called the *sacral cornua*, and articulate with the first coccygeal vertebra, with which also the inferior surface of its dwindled body, situated at the apex of the sacrum, articulates. The sacrum sometimes consists of six vertebrae, and occasionally is surmounted by a vertebra with a thick lateral mass of sacral character on one side and a lumbar transverse process on the other.

In the erect posture, the sacrum is so placed that the ventral border of the auricular surface is horizontal. Toward the base, the dorsal surface of the sacrum is therefore superior in position, and the ventral surface inferior; and the ventral being the broadest part, the sacrum articulates with the pelvic bones, not like the keystone of an arch, but with the broad end of its dorso-ventral wedge downmost.

The coccyx is the name given to the dwindled vertebrae beyond the sacrum, which are described as one bone on account of their being usually united into one piece before being joined to the sacrum. The first coccygeal vertebra has a broad flat body with two transverse processes projecting from its sides, and a pair of *cornua* striking up from behind it to complete, with the sacral cornua, a pair of foramina for the fifth pair of sacral nerves. The remaining coccygeal vertebrae vary from two to four, but are usually three. The second has an upper and a lower flat surface, and mere indications of transverse processes. The other two are reduced to nodules. The three last are usually united into one bone before being united with the first. The period of union of coccyx and sacrum is variable, but is earlier in the male than in the female, in whom such union may cause difficulty in parturition.

The articulated column presents various curves for consideration. If the line of the front of the bodies of the vertebrae be followed, there is seen in the neck a marked convexity, which is succeeded by a concavity reaching its deepest about the sixth thoracic vertebra. Thence the line slopes forwards to the lumbar convexity which projects much further

forwards than any other part of the column, and is such that the column at this part may sometimes be felt through the abdominal wall in a lean patient. The lumbar convexity is succeeded by the sacral concavity extending far backwards. In addition to these curves, there is also a slight deviation to the right in the upper part of the chest, probably connected with the fact that the aorta lies at that part on the left side of the column. More important is the circumstance that when the pelvis is in an oblique position by only one knee being straightened, which is the natural mode of standing, the column is thrown into temporary lateral curves, which, in combination with increase of the mesial curves, produces a spirality well adapted to give greater spring and to increase the stability of balance. The exaggeration of such natural positions gives rise to the lateral curvature known as a pathological condition.

The great development of mesial curvature is specially characteristic of man, and connected with the maintenance of the erect posture by balance. At birth the column is very flexible, and the cervical convexity is favoured by the head of the infant being no longer bent upon the chest, but thrown backwards. The lumbar convexity makes its appearance somewhat later. To stretch the lower limbs of an infant there is required not only the extension of the hip joint, but still more the bending backwards of the lumbar part of the column, so as for the first time to produce the convexity, which soon becomes permanent.

Besides the curves, there are other peculiarities of the human vertebral column connected with the assumption of the erect posture. The lumbar vertebrae are massive to support the accumulated weight above them, while the cervical vertebrae are light as compared with those of many animals, the head being habitually supported by balance, and not suspended at the extremity of a column projecting forwards as in quadrupeds. Also the pillar of support formed by the bodies of the vertebrae projects well forwards into the thoracic and abdominal cavities so as to have the weight distributed round it; and, to effect this, the transverse processes at their origins are thrown backwards by the intervention of pedicles between them and the bodies, and the thoracic transverse processes have a well-marked backward inclination. The imbricated thoracic spines are also characteristically human. In many mammals the dorsal projection of these processes is such as to form prominent withers affording room for muscles at their sides; while in man the mass of muscles straightening the back is accumulated most largely in the loins.

THE RIBS.

There are twelve pairs of ribs developed as separate bones, and they articulate with the twelve thoracic vertebrae. They are prolonged forwards by *costal cartilages*, of which the first seven pairs articulate anteriorly with the sternum, while the remaining five are pointed, three

of them adherent each to the costal cartilage above and the two last lying free in the muscular wall. Having regard to these differences, the first seven ribs are called *sternal* or *true*, and the remaining five are distinguished as *asternal* or *false*, while the eleventh and twelfth are called *floating* ribs.

In an early embryonic condition each rib was part of the same cartilage as the corresponding vertebra, but in process of development the posterior end or *head* of each, with the exception of the first and the last three, was displaced upwards so as to articulate with the body of the vertebra above, as well as its own; and the head presents, therefore, an upper and a lower articular surface separated by a ridge for an interarticular ligament. Each rib, with the exception of the eleventh and twelfth, articulates with the transverse process of its own vertebra by a part called the *tubercle*, which presents two portions—an articular surface looking backwards and downwards, and, outside the articular surface, a ridge for the posterior costo-transverse ligament. The part between the head and the tubercle is the *neck*, and the remainder of the rib is the *shaft* or *body*. The back of the shaft is crossed by an oblique roughness, called the *angle*, marking the outermost attachments of the erector spinae muscle. The neck is longest in the first rib, and getting gradually shorter disappears in the eleventh and twelfth. On the upper surface the neck has a groove with a ridge in front of it. The shaft becomes more compressed as it is followed forwards, and in most ribs is somewhat expanded in front. It ends in a shallow depression into which the costal cartilage fits, inseparably united to the bone. On the inner surface of the shaft inferiorly is the *subcostal groove*; extending outwards from the tubercle, best marked at the angle, and

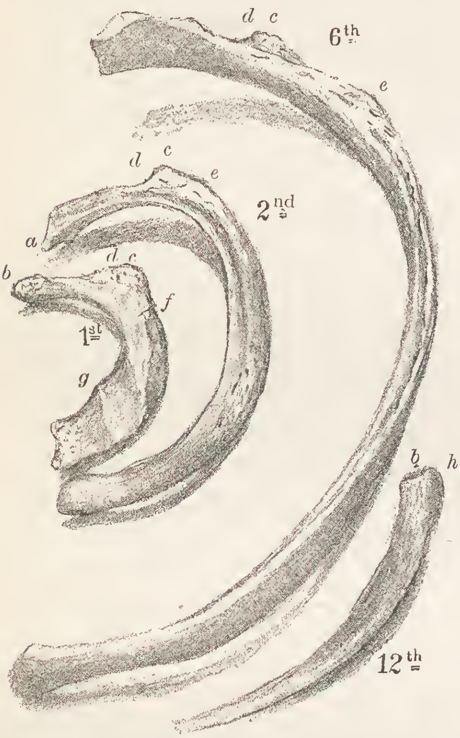


Fig. 129.—First, Second, Sixth and Twelfth Ribs of Left Side, from above. *a*, Interarticular ridge of head; *b*, single articular facet of head of first and twelfth; *c*, rough elevation of tubercle; *d*, opposite articular facet of tubercle, itself not seen; *e*, angle; *f*, insertion of scalenus medius; *g*, tubercle at inner end of line of insertion of scalenus anticus, between the grooves of the subclavian artery and vein; *h*, on the twelfth corresponds with the tubercle of other ribs. The shadows show the vertical curves of the ribs.

dying away gradually beyond, it shelters the intercostal vessels and nerve. A *supracostal groove* is well marked for a variable distance forwards from that on the neck.

The fully developed ribs, when looked at from above, present two curves, the part extending from the head to the angle forming an arc of a smaller circle than that in whose circumference the part in front of the angle lies. When looked at in profile, they present a double curve, the slope being diminished at the angle and again increased at the anterior end, so that, when laid on a flat surface, the angle and the tip touch it while the intervening part does not, and the neck strikes upwards. They are also twisted on themselves, so that if at the middle they are held with the surfaces looking outwards and inwards, the deep surface of the neck and the superficial surface of the fore part of the shaft both look upwards as well as forwards.

The first rib is remarkably short. The head is small, with only one articular facet. The neck is long, slender at the head, and thick at the prominent tubercle. The body has its superficial and deep surfaces looking upwards and downwards, and is broadened out like a scimitar. When the neck is held in the horizontal, which is its natural position, the body is slightly curved downwards, especially at the outer border midway forwards from the tubercle; and this curve is no mere result of muscular traction, for it exists even before birth. On the upper surface, more than half way forwards, there is a roughness prolonged into a small tubercle at the inner margin, marking the insertion of the scalenus anticus muscle, and separating two slight depressions, the posterior corresponding with the position of the subclavian artery and the anterior with the subclavian vein; while the part behind the posterior groove is extensively rough, and gives insertion to the scalenus medius.

The second rib has its superficial surface looking upwards and outwards, and its upper and inner border is about twice as long as the inner border of the first rib. In its shaft it is not only narrower than the first rib, but narrower than any of the succeeding ribs down to the tenth. Superficially, about midway forwards, it has a notable rough thickening where the serratus magnus is attached.

The tenth rib has one articular surface on its head, and one at the tubercle.

The eleventh and twelfth ribs are known by their shortness and very slight curvature, and by having only one articular facet, which is on the head; while the angle is absent from both, or may be barely perceptible on the eleventh. The twelfth is always considerably the shorter of the two, and is usually from two to four inches in length. Both have a distinct twist, turning the fore part of the inner surface slightly upwards.

Variations. The ribs are sometimes increased in number on one or both sides by a small rib attached to the first lumbar vertebra. An

articulated rib sometimes occurs in connection with the seventh cervical vertebra; it may be of considerable length, and in front is usually free, but may be united to the rib following. Sometimes, in a thorax otherwise normal, one of the ribs bifurcates in front, and is prolonged forwards by cartilages which approach or unite at the sternum.

The costal cartilages take origin from the ribs in an oblique line extending from above downwards and outwards. The first seven, and not unfrequently the eighth (Cunningham), are prolonged to the sternum. Of these the first is the shortest and strongest, and is the only one which is united to the sternum by direct continuity in the same way as it is united to the rib. The others are united by movable articulation, usually with the intervention of a small synovial cavity, or, in the case of the second, third and fourth, two such cavities, an upper and a lower. From the third downwards the cartilages slope upwards with an increasing slope to reach the sternum. Those which fail to reach the sternum are pointed at the extremity; the eleventh and twelfth being short and free, while the others are prolonged forwards, and become adherent for a considerable distance by fibrous union, each to the cartilage next above it, sometimes presenting a considerable temporary increase in breadth, and even the intervention of an articular cavity. Though the costal cartilages are usually invaded, as life advances, by calcification in the interior, and may be incrusted with bone on their surface, this ossification is irregular, and the positions of the ends of the ribs remain constant.

THE STERNUM.

The sternum consists of segments which unite at different periods one with another. Three portions are recognized: the uppermost, the *manubrium*, extends down to the second costal cartilage, and only in advanced life becomes united by bone to the next portion. The lowest part, the *ensiform process*, projects downwards from the insertion of the last sternal costal cartilages, and is seldom united to the part above it till middle age. The *body*, or part intervening between the manubrium and ensiform process, presents two obvious segments opposite the second and third intercostal spaces, and below these a remaining portion on which the traces of having belonged to more than one segment of the skeleton are more obscure.

The **manubrium**, or *presternum*, is the strongest and broadest part. It has a somewhat convex superficial surface, a flat deep surface, and four borders. Its upper border is thick and consists of three parts, an interclavicular depression (*incisura semilunaris*), and on each side of this an articular surface looking upwards, outwards, and a little backwards, for the sterno-clavicular articulation, concavo-convex both from behind forwards and also from without inwards. The lateral border exhibits superiorly a vertically placed rough surface where the first costal cartilage joins it, and, beneath this, is concave and smooth as far as the angle separating it

from the comparatively narrow inferior straight border. There a small facet intervenes which, together with a similar facet on the body of the sternum, makes the notch of insertion of the second costal cartilage.

The **body**, or *mesosternum*, increases in breadth from its upper end to the insertion of the fifth costal cartilage. Two distinct transverse ridges on the superficial aspect mark the junction of its first and second segments, and of the second and third; and opposite these ridges the edges are notched to receive the third and fourth cartilages. More than half way down on the remaining part are the notches for the fifth pair of costal cartilages, with an obscure ridge between them, while, still lower, are two pairs of notches for the sixth and seventh, placed one close above the other, those for the seventh marking also the ensiform process.

FIG. 130.—THE STRRNUM from the front.

The **ensiform** or **xiphoid process**, or *metasternum*, is a thin projection with its deep surface continuous with that of the mesosternum, while, superficially it is depressed at its origin. It often remains wholly or in part cartilaginous till a late period of life, and is sometimes straight and narrow, sometimes expanded, perforated, or bifurcated. Sometimes it projects forwards beneath the skin.

The sternum increases in variability from above downwards, the lower half of the mesosternum being in some instances much broader than in others, and occasionally perforated.

A pair of *episternal ossifications* were first described by Breschet, situated one at each side of the interclavicular depression. Luschka described a pair as large as pisiform bones; and a specimen with a pair quite as large was in the Anatomical Museum in Galway when I was professor there.

THE THORAX.

The thoracic skeleton has its greatest strength behind, its greatest height in the plane upwards from the tips of the twelfth ribs, and is short in front. Narrow above, it attains its greatest breadth at the level of the eighth rib, and its greatest antero-posterior diameter toward the sides, at the level of the lower end of the sternum, where the ribs arch backwards, forming the *costal fossae* to lodge the greatest breadth and depth of the lungs, and leave between the angles and the row of spines behind a furrow in which lie the muscles of the back. But in the mesial plane, the diameter from sternum to vertebral column is much narrower, on account of the characteristically human projection of the column into the

interior, which also increases the proportionate breadth of the cavity. The bodies of the vertebrae from about the fifth form a pillar sloping downwards and forwards at an angle of about 15 degrees with the vertical, while the average slope of the sternum may be about 25 degrees. Below the ninth rib the thorax is slightly narrower, and the eleventh and twelfth ribs have their upper margins distinctly everted.

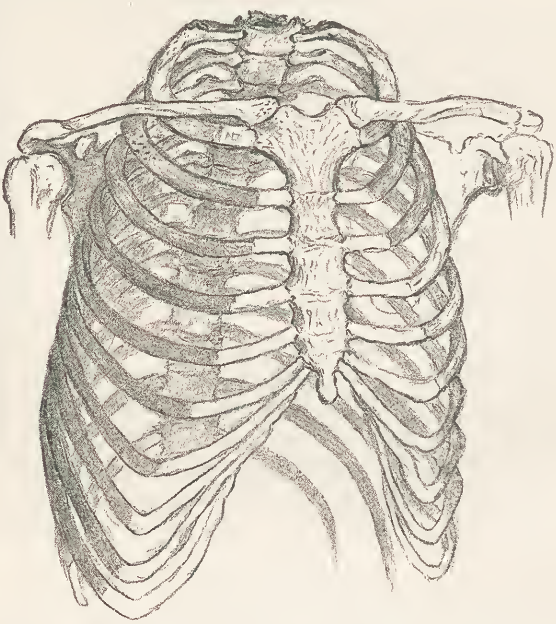


FIG. 131.—THORACIC SKELETON, with the clavicles, scapulae, and heads of humeri in position to show how the apparent shape of the chest is affected by the superposition of the shoulders.

In the female there is little increase of breadth below the fifth or sixth rib, but more rapid increase above that level; and this makes the heaving of respiration more obvious in the upper part of the chest, it being principally in that part that in inspiration small arches are replaced by larger at any particular level. In the child the height of the thorax is short as compared with its girth. In old age the arches of the ribs are liable to be flattened laterally. In the globular chest of emphysema the convexity of the sternum is increased. In shoemakers there is often a deep depression at the lower end of the sternum caused by pressure of the last.

ARTICULATIONS OF THE AXIAL SKELETON.

The vertebral column is joined together by synovial joints, intervertebral discs and ligaments.

The synovial articulations between the articular processes are surrounded by fibrous capsules.

The intervertebral discs are each divisible into a central pulp and a laminated white-fibrous structure surrounding it and graduating into it. The pulp is soft, yielding, resilient and tough. (For its structure, see p. 38.) The laminae consist of thin layers of fibres of tendinous lustre disposed obliquely, those of one layer decussating with those of the layers in contact with it, and the deep layers more nearly horizontal. When a disc is divided, the cut laminae alternately reflect more or less light to the eye, and being relieved from tension, press the cut pulp into a convex form. The discs are thickest in the lower lumbar region, reaching to two fifths of an inch in depth. In the upper half of the chest they are very thin. By inequality of depth in front and behind they take part in the formation of the vertebral curves. Between the non-central parts of the bodies of the cervical vertebrae there is invariably a synovial space left on each side, interrupting the disc, as was pointed out by Luschka.

The anterior common ligament is a longitudinal band extending in front of the vertebrae and the intervertebral discs down to the sacrum. It begins above as a narrow fasciculus adherent to the fibrous sheet between atlas and occipital bone, and sometimes termed *accessory occipito-atlantal ligament*, and increases in breadth more and more as it descends. It is strong in the middle line, its superficial fibres passing over a number of vertebrae; but it thins away at the sides, and its deep and lateral fibres stretch vertically between the neighbouring margins of vertebrae.

The posterior common ligament, behind the bodies of the vertebrae, begins as a broad band above, at the axis, in continuity with the long occipito-axial ligament, and narrows as it descends, till it ends by tapering on the backs of the bodies of the sacral vertebrae. It has a dentated appearance; its fibres being more gathered together behind each vertebra, where a vein emerges on each side from underneath it, while it has a spreading attachment to each disc and the contiguous margins of vertebrae.

The ligamenta subflava are strong bands of yellow-elastic tissue which extend vertically between the laminae, from the axis to the sacrum; their inner edges are in contact, and they are attached to the roughnesses on the lower and upper edges of successive laminae. They are so far on the stretch in the erect posture, that when the series of laminae is detached in one piece kept together by them, it is two or three inches shorter than the column from which it has been removed.

The supraspinous ligament is a continuous band of fibres joining the tips of the spines together, from the seventh cervical to the first sacral.

The ligamentum nuchae is continued up from the spine of the seventh cervical vertebra, continuous with the supraspinous ligament, its superficial fibres extending to the occipital protuberance, and the deeper fibres successively to the occipital crest and the cervical spines from above downwards. The superficial part is little more than a raphe between the trapezii and splenii muscles of opposite sides, and the deep part is a mere intermuscular septum. It owes its name to being obviously homo-

logous with the important yellow-elastic ligamentum nuchae by which, in the horse and other animals, the head is kept without muscular effort from hanging too low down.

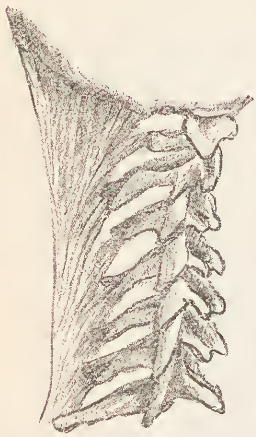


Fig. 132.—Ligamentum Nuchae, with its attachments to the cervical vertebrae and occipital bone.

The interspinous ligaments are unimportant septa between the spines; and still less important are the scattered fibres called *intertransverse ligaments,* found in the dorsal and lumbar regions.

The sacro-coccygeal and the coccygeal ligaments are dwindled representatives of intervertebral discs, anterior and posterior common ligament, and joints of articular processes, and require no special description.

The atlas and axis are united to one another and to the occipital bone by joints and ligaments differing from those of the rest of the column.

The synovial articulations between the atlas and occipital condyles, and those between the inferior articular surfaces of the atlas and superior articular surfaces of the axis are surrounded by fibrous capsules, and the capsule of each of the latter joints is strengthened at the inner part of its posterior aspect by a strong *accessory ligament.* The articulation between the odontoid process of the axis and the anterior arch of the atlas has no fibrous capsule.

The long occipito-axial ligament,[1] already alluded to in connection with the posterior common ligament, prolongs that ligament from the back of the body of the axis to the basilar process of the occipital bone.

The transverse ligament of the atlas, in front of the long occipito-axial ligament and concealed by it, is attached on each side to the rough surface on the inner side of the lateral mass, and separates from the proper ring of the atlas an anterior compartment in which the odontoid process is grasped. At its attachments its fibres are gathered together, while in the middle it is pushed back by the odontoid process and is flattened out. From this middle part a short and thin band passes down to the body of the axis, and a longer and slenderer band passes up to the front of the foramen magnum; these are termed the superior and inferior *appendages,* and together with the transverse ligament form the *cruciform ligament.*

The lateral odontoid or *check ligaments* are a pair of very strong rounded bands, extending from the rough sides of the head of the odontoid process outwards to the rough surfaces inside the occipital condyles. Some of

[1] Known also as *posterior occipito-axial ligament, apparatus ligamentosus, ligamentum latum epistrophei,* and catalogued by the German committee among the ligaments of the atlanto-epistrophic articulation as *membrana tectoria.*

their fibres are continuous from side to side. They are both relaxed when the head looks straight forwards, and both of them tightened when it is rotated to either side; hence they check too great rotation.

The middle odontoid (improperly called *suspensory*) *ligament* consists of a small bundle of loose tissue, containing within it, in the young subject, the remains of the notochord, as it extends up to the occipital bone in front of the foramen magnum. It has no ligamentous function.

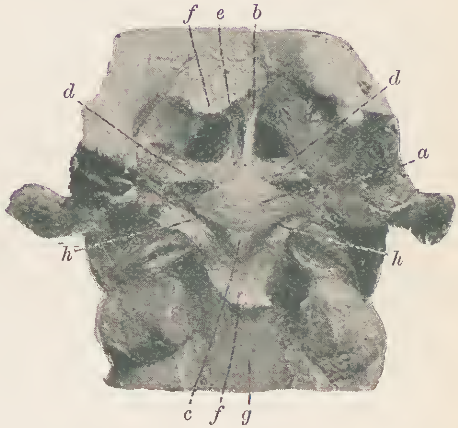


FIG. 133.—ARTICULATIONS OF ATLAS, AXIS AND OCCIPITAL BONE seen from within the spinal canal after division of *f*, *f*, the long occipito-axial ligament. *a*, Transverse ligament of atlas; *b*, *c*, superior and inferior appendages; *d*, *d*, cheek ligaments; *e*, middle odontoid ligament; *g*, posterior common ligament; *h*, *h*, accessory ligaments of atlanto-axial articulations. The posterior gap is shown between the opposed articular surfaces of the atlas and axis.

The anterior occipito-atlantal and *anterior atlanto-axial ligaments* or *membranes* are fibrous expansions uniting the anterior arch of the atlas with the front of the foramen magnum and the body of the axis respectively, and are strengthened by the narrow mesial band by which the anterior common ligament commences.

The posterior occipito-atlantal and *posterior atlanto-axial ligaments* or *membranes* are very thin white-fibrous expansions uniting the posterior arch of the atlas with the back of the foramen magnum and the laminae of the axis. They take the place of ligamenta subflava.

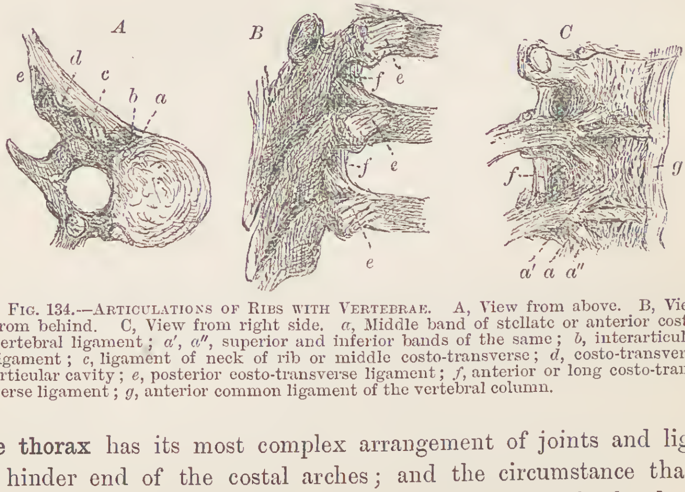


FIG. 134.—ARTICULATIONS OF RIBS WITH VERTEBRAE. A, View from above. B, View from behind. C, View from right side. *a*, Middle band of stellate or anterior costo-vertebral ligament; *a'*, *a''*, superior and inferior bands of the same; *b*, interarticular ligament; *c*, ligament of neck of rib or middle costo-transverse; *d*, costo-transverse articular cavity; *e*, posterior costo-transverse ligament; *f*, anterior or long costo-transverse ligament; *g*, anterior common ligament of the vertebral column.

The thorax has its most complex arrangement of joints and ligaments at the hinder end of the costal arches; and the circumstance that there are synovial joints between the bodies of vertebrae and the heads of ribs,

and others between transverse processes and the tubercles of ribs, has led to the distinction of *costo-vertebral* and *costo-transverse articulations.*

The anterior costo-vertebral ligament or *stellate* or *radiate ligament* of the head of the rib extends from the front of the head of each typically articulated rib three bands—an upper, sloping up to the vertebra above, and lying in front of the upper joint; a lower, sloping downwards in like manner in front of the lower joint, and a shorter and narrower band extending directly inwards to the intervertebral disc.

The interarticular ligament is a strong, although thin, band stretching from the interarticular ridge of the head of the rib into the intervertebral disc, and separating the upper articulation of the head of a typical rib from the lower.[1]

The posterior costo-transverse ligament is a definite and strong flat band extending from the ridge of the tubercle of the rib downwards and inwards to the transverse process of its vertebra, behind the costo-transverse articular cavity.

The middle costo-transverse ligament, ligamentum colli costae, or *interosseous ligament* consists of horizontal fibres uniting the back of the neck of the rib to the front of the corresponding transverse process, and filling up the interval between the costo-vertebral and costo-transverse articular cavities.

The long (or *superior*) *costo-transverse ligaments* consist of two sets of bands irregularly developed in different intercostal spaces, and uniting the neck of the rib with the vertebra above. The anterior and outer bands extend between the ridge on the neck of the rib and the tip of the transverse process above; the posterior and inner bands are attached inferiorly behind the groove of the neck of the rib and superiorly near the root of the transverse process.

The anterior thoracic joints are comparatively simple. The junctions of ribs with costal cartilages, of pieces of the sternum one with another, and of the sternum with the first costal cartilage are not properly to be looked on as joints, any more than the union of shaft and epiphyses in a young bone. But true sterno-chondral articulations occur in connection with the cartilages of the sternal ribs succeeding the first. Most commonly two synovial cavities separated by an *interarticular septum* are found in connection with the second costal cartilage; and descending from this, two cavities

[1] The interarticular ligament derives additional interest from the circumstance that in many mammals it is replaced by a *ligamentum conjugale costarum,* which crosses over between the intervertebral disc and the posterior common ligament, and joins the head of the rib to its fellow. In ruminants the conjugal ligament is attached by other fibres to the body of the proserial vertebra, but it is not so in carnivora; and in both there is a single synovial cavity continued from side to side, representing the two pairs of cavities connected with the heads of a pair of ribs in man. The transverse ligament of the atlas and the lateral odontoid ligaments belong to the same series of transverse fibres, and, in so far, may be regarded as conjugal ligaments (Cleland, 1859 and 1861).

become less frequent; while, in connection with the cartilage of the lowest sternal rib, most frequently there is no synovial cavity, and a single cavity becomes more frequent as we ascend from this. Interchondral synovial articulations occur variably between successive costal cartilages from the fifth to the ninth. On the deep surface the sternum ribs and cartilages are united by continuous periosteum and perichondrium, strong, but not otherwise remarkable; and on the superficial aspect of the sternum a decussating arrangement of strong fibres extends across the middle line and over the costal cartilages. Also between the costal cartilages, tendinous fibres continuous with the external intercostal muscles bind the cartilages together, and are stronger and shorter below, where they bind the asternal cartilages.

MOVEMENTS OF THE AXIAL SKELETON.

The vertebral column allows mesial and lateral angular movement, rotation and circumduction, to different extents in different regions. Mesial flexion and extension are allowed most freely in the cervical region, and next to it in the lumbar. The neck cannot only be flung backwards till the edges of the inferior articular surfaces are caught on depressions, often well marked, on the laminae below (Bruce Young), but it can be bent forwards so as to throw the fronts of the bodies into a concave curve. The lumbar vertebrae can be thrown back considerably, but cannot be bent forwards further, as a rule, than is sufficient to bring the fronts of the bodies into a straight line by undoing the natural convexity forwards. Conversely, in the thorax the column can be straightened so as to undo the normal concavity forwards, but cannot be bent further back. Lateral flexion is practically allowed in all the three regions of the movable part of the column, but while it is of a pure description in the lumbar region, and almost if not altogether so in the thoracic region, it is not so in the cervical region, because the obliquity of the cervical articular surfaces compels an upward gliding of one on another to be accompanied by a forward motion and *vice versâ.* Lateral flexion in the cervical region is therefore always accompanied with a certain twisting movement. But, neither is pure rotation possible in the neck, seeing that the planes of contact of its articular surfaces do not form arcs of circles; the apparent rotation is rather a circumduction, produced by oblique twists and compensatory backward and forward movements. In the lumbar region rotation is completely prevented by the locking of the articular processes. In the thoracic region alone is pure rotation allowed, the axis of rotation corresponding nearly with the fronts of the bodies of the vertebrae.

The atlanto-axial articulation, although it is distinctly a pivot-joint, and that by means of which the head is enabled to be turned from side to side on the top of the column, is not so constructed as to allow a perfectly simple rotation round a vertical axis. It has been pointed out that the inferior articular surfaces of the atlas do not fit exactly to the

superior articular surfaces of the axis when placed symmetrically over them; but that on the contrary a gap is left on each side, in front and behind, in consequence of the axial surfaces being each divided into an anterior and a posterior part, with a slight elevation between. If, however, the atlas be rotated, the anterior facet of the axial surface of one side and the posterior facet of the other side come into perfect contact with the atlas, so that there is much greater stability than when the parts are placed symmetrically. The transverse process of the atlas is depressed on the side toward which the head is turned, and rises on the other.

The atlanto-occipital articulation is principally adapted for flexion and extension, but admits of a distinct, though often overlooked, oblique rotation when the head is midway between the extremes of these positions. The articular surfaces are not spherical, the occipital condyles being divided by an oblique ridge into two parts, and there cannot, therefore, be continuous conformability in different positions. They are most extensively in contact in extreme over-extension, when the posterior edges of the atlantal surfaces are locked in depressions at the back of the condyles, and the posterior tubercle presses against the back of the foramen magnum, so that no rotation is possible. But when the occipital bone is flexed forwards, a gap is opened between the condyles and the backs of the atlantal surfaces, and this increases until complete flexion is reached, in which the atlas is locked against the occipital bone in front of the condyles, and rotation is again impossible.

Fig. 135.—Articulations of Atlas, Axis and Occipital Bone from the front, placed as when the head is thrown back and twisted to the left. *a*, *a*, Occipital condyles; *b*, *b*, inferior articular surfaces of atlas; *c*, anterior common ligament; *d*, narrow occipito-atlantal commencement of the same.

The ribs move round their heads, the interarticular ligament, where present, being the centre of the movement. The plane of movement is determined by the plane of contact of the tubercle with the transverse process, which from the fourth rib downwards is oblique and compels the rib to glide backwards when pulled upwards, and forwards when depressed. By this means the shafts are thrown backwards to such an extent, when elevated, that the capacity of the chest is greatly increased in that direction in inspiration. The anterior extremities of the sternal ribs, from the second downwards, revolve round the sterno-chondral articulations, and when the muscles are removed a costal arch can be made to move upwards and downwards round its two extremities like the

handle of a bucket. Also, in a dissected thorax, it may be noticed that when the sternum is moved upwards and downwards, the first costal arch, being the shortest of those attached to it, exhibits the greatest amount of angular motion. But in respiration, owing to the mode in which the elevating force is applied, and the resistance opposed to the rise of the first rib, the movements of the chest are quite different. In quiet respiration in the healthy chest the first rib and the top of the sternum remain unelevated, while the lower end of the sternum is raised and slightly advanced; and in forced respiration, although the first rib and top of the sternum are raised, their movement is not to the same extent as that of the sequent ribs and the lower end of the sternum. The body of the sternum in respiration is pushed by the successive costal cartilages when these are raised, and offers resistance to them; also, the backward sweep given to the hinder parts of the shafts would obviously cause their extremities, if free, to retreat from the middle line. By these two factors the larger sternal ribs are bent on themselves, and the angles above their junctions with their cartilages are forcibly opened in each inspiration, so that the parts spring back when the respiratory effort ceases. It can easily be seen in healthy respiration that the thorax is increased in size in every direction, namely, upwards, downwards, backwards, forwards, and transversely. But when the lower end of the sternum is abnormally turned in underneath the manubrium, it can no longer be pushed forwards by the costal cartilages.

The movements of respiration can be demonstrated both on the dead subject and on the living to be influenced greatly by the position of the vertebrae. When the thoracic part of the column is extended, the ribs are raised and the intercostal spaces widened; when it is bent, the reverse takes place. In consequence of this, if the body be bent forwards and a full breath be taken and the breath held, a considerable amount of additional air can be inhaled when the erect attitude is resumed. Conversely, if, with the back well straightened, as deep an expiration as possible be made and the breath then held while the body is bent, an additional expiration is permitted.[1] When the thoracic vertebrae are rotated, the ribs of the side toward which the head is turned are elevated, and those of the opposite side are depressed, while costal respiration is interfered with.

The whole axial skeleton is much more frequently balanced in an unsymmetrical than in a symmetrical position. The position termed in military drill "standing at ease" is much more natural than that which is understood by "attention"; that is to say, that the natural position in standing is with the main weight supported upon one limb, the knee of which is straight, while the other limb has the knee bent. In such circumstances the pelvis is necessarily thrown into an oblique position,

[1] These facts have been overlooked by physicians in measuring vital capacity, and even to some extent in resuscitating the drowned.

and the lumbar vertebrae with it, and the parts higher up are thrown into compensatory curves; the mesial curves are exaggerated, and lateral curves are produced, the lumbar vertebrae presenting a concavity toward the higher side of the pelvis, and all the joints above being placed in oblique positions, including the atlanto-axial and atlanto-occipital articulations.

DEVELOPMENT OF AXIAL SKELETON OF TRUNK.

Both in birds and mammals a thickening has been observed on the ventral aspect of the sheath of the notochord opposite each pair of muscle-plates, but continued outwards with such an obliquity as to lie at the sides in the interval between that pair and the next. This is the *primitive arch*, and in the atlas persists (A. Froriep). It is followed immediately in the sheath itself by a ring of cartilage with whose upper margin, in vertebrae other than the atlas, it becomes blended. The notochord is constricted and soon obliterated where each ring of cartilage grasps it, but is enlarged in the intervals destined for the intervertebral discs. Laterally, the vertebrae extend outwards to form the ribs and costal cartilages; while, dorsally, they give off the neural arches which for a time pass only partly round the spinal canal. The first primitive arch forms the atlas, while the corresponding cartilaginous ring of the notochordal sheath is converted into the odontoid process.

In the human embryo chondrification begins at the commencement of the second month, but the neural arches are not closed in with cartilage till the fourth month. In an embryo an inch long with ossification of the clavicle just begun, and probably, therefore, six weeks old, I observed that the upper costal arches had extended round to the middle line in front, that the others had attained their full relative length, and that at the site of the tubercles the ribs were still continuous with the vertebrae, while a complete line of separation between rib and vertebra extended inwards from this. The oblique position into which the vertebra is thrown as development proceeds is therefore effected by rotation round the transverse process, and this accounts for the head of the rib being displaced upwards into contact with the body of the vertebra above.

Fig. 136.—Vertebra of Embryo one inch long, with pair of ribs continuous with it at the tubercles.

The sternum, there can be no doubt, is at first laid down in the form of two lateral strips at right angles to the tips of the costal cartilages. It is impossible, however, to refer these strips to prolongations from the costal tips. Judging from the appearance in the third month, the manubrium may be originally continuous with the first pair of costal cartilages, but the mesosternum takes its origin distinct from costal cartilages, and

the xiphosternum is at first separated from the mesosternum by the sixth and seventh costal cartilages meeting in the middle line.[1]

Ossification. The vertebrae from the third cervical to the fifth sacral have three principal centres of ossification, namely, a pair appearing in the seventh or eighth week to form the arch and processes, and a mesial ossification, the *centrum*, appearing immediately after. The osseous laminae are united in the first year after birth, and the arches so formed begin to be joined to their centra in the third year. The seventh cervical vertebra has, in the anterior or costal parts of its transverse processes, an additional pair of osseous nuclei appearing in foetal life and detectable for a variable period, and similar nuclei have been seen to occur in the sixth, fifth and second vertebrae. So also the three upper sacral vertebrae, and sometimes the fourth, have each a pair of additional osseous centres, costal in their nature, which make their appearance successively in later foetal life and form the bulk of the lateral masses.

Epiphyses, or supplementary centres of ossification, appearing about the eighteenth year, and recognizable till about twenty-five, are found in connection with both the bodies and processes of vertebrae. The bodies have each an upper and a lower epiphysial plate extending as far as the circumference, near which they are best developed; but in the centre, unlike the corresponding epiphyses in other animals, they are deficient. Two other epiphyses are at the tips of the transverse processes and spine; and, in the lumbar region, two additional surmount the mammillary processes. The sacrum possesses, besides upper and lower epiphyses of the body of each vertebra, two pairs of lateral epiphyses peculiar to it. The upper and more important of these corresponds in extent with the auricular surface, and is united earlier to the first than to the second and third vertebrae, thereby allowing the second sacral vertebra to continue to increase in breadth (Cleland, 1889). Like the rest of the column, the sacrum is not thoroughly complete till the twenty-fifth year or later.

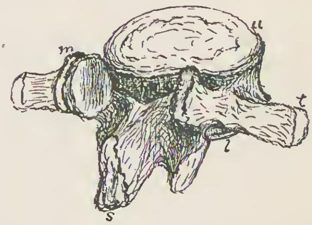


Fig. 137.—Lumbar Vertebra of Adolescent, showing epiphyses. *u* and *l*, Upper and lower epiphyses of the body; *s*, that of the spine; *t*, that of the transverse process; *m*, that of the mammillary process.

In the *atlas* the lateral masses and posterior arch are formed from a pair of ossifications corresponding with those of the arch in other vertebrae. At birth, these are united by a mere ligamentous band in front of the odontoid process; but, during the first year, cartilage appears, and either one, two or three osseous nuclei, which normally become blended with the

[1] The origination of the sternum in lateral parts explains the well-known case of M. Groux in whom the two halves remained ununited, and could be pulled separate by the great pectoral muscles when the hands were clasped. Less complete division also occurs. The original distinctness of the lower parts of the sternum from the costal arches may well be kept in mind when comparing with the chelonian plastron.

lateral masses in the fifth or sixth year. The odontoid process of the *axis* is, as has been explained, in reality, part of the first vertebra, being developed round the notochord which was continued through it into the base of the skull: but it presents in the human subject a pair of centres of ossification, which, before the seventh month, unite to form a centrum larger than the proper centrum of the axis. This mass bears trace of its double origin in presenting a mesial notch above and below, and not only forms the odontoid process but extends some distance lower than the level of the superior articular surfaces of the axis. The proper centrum of the axis has also been recently seen in the form of a pair of separate nodules in the sixteenth week, and of a bilobate nucleus in the seventeenth (Macalister, 1894). In four instances out of thirty-one, Macalister has found in the axis an ossification intervening in the fore part of the interval between pedicle and centrum, interesting as apparently homologous with the anterior ossifications of the atlas. A separate nodule is sometimes seen at the summit of the odontoid process, and in young monkeys a complete cap may be found in this situation. The interval between the odontoid centrum and the centrum proper of the axis becomes limited by smooth surfaces before disappearing, and, within it, a certain amount of osseous deposit takes place. But the interval disappears altogether, both in front and behind, although on section it is often observable in the adult bone (Cunningham). In various animals, as in the sheep, a more notable centre of ossification forms a wedge ventrally placed between the odontoid process and the axis proper; and in a young polar bear I observe both the inferior epiphysis of the odontoid process and the superior epiphysis of the centrum of the axis distinct.

In the *ribs* ossification begins about the same time as in the vertebrae,

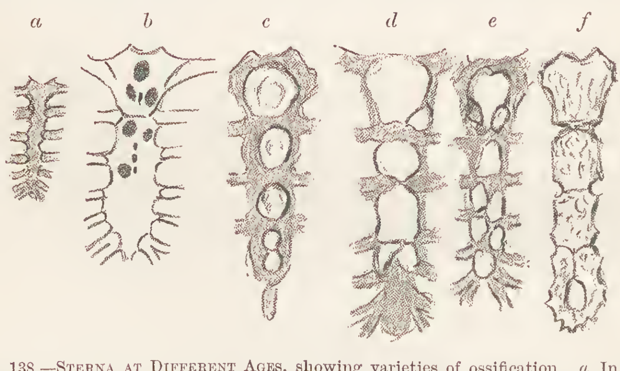


FIG. 138.—STERNA AT DIFFERENT AGES, showing varieties of ossification. *a*, In third month of foetal life, before ossification has set in; *b*, from an older foetus showing a very peculiar set of centres of ossification; *c*, *d*, *e*, varieties of osseous centres in three sterna of infants; *f*, from a child ($\frac{1}{3}$), showing the lower part of the mesosternum in two lateral parts, with a foramen in the middle.

from a single centre. A small epiphysis at the head and another at the tubercle appear about the eighteenth year, and, like those of the vertebrae, are united with the main bone about the twenty-fifth year.

The sternum is very variable in its ossification. The manubrium may have one or several nuclei (six have been figured) which, however, soon unite. In the remainder of the sternum the nuclei are mesial or in pairs, or may even be both lateral and mesial, and most frequently unite to form single segments, but sometimes remain distinct for years. The parts opposite the second and third intercostal spaces constitute each a temporary segment; the remainder of the mesosternum may have a series of one, two or three nuclei or pairs of nuclei. Ossification begins in the manubrium about the sixth or seventh month of foetal life, and nuclei appear in the mesosternum in series from above downwards for a year or more after birth. I observe a distinct osseous centre in the xiphoid process of a child of two years, but this is unusual. The mesosternum remains in three segments till after puberty, and is not usually completed till the twenty-fifth year.

II. THE SKELETON OF THE LIMBS.

THE UPPER LIMB.

The upper or pectoral limb, often called in human anatomy the superior extremity, consists of shoulder, arm, forearm and hand. To the shoulder-girdle or pectoral arch belong the clavicle and the scapula. In the arm there is only one bone, the humerus; in the forearm are the radius and ulna; and in the hand there are as many as twenty-seven bones, which are arranged in three groups, the carpus, the metacarpus and the phalanges.

The Clavicle.

The clavicle or collar-bone unites the manubrium of the sternum with the acromion process of the scapula. It is the only bone by which the upper limb is articulated to the axial skeleton, and it furnishes the fulcrum on which the raised arms are stretched outwards from the body and approached again to the middle line.

In its inner three-fourths the clavicle is curved with the convexity in front, while the outer fourth is bent forwards so as to produce a convexity behind. There is also a slight curvature in the vertical plane, which, combined with the horizontal curves, gives a spiral twist, often well marked in slender specimens, and contributing strength and spring in shocks conveyed through the limbs. It is stout at the inner end and flattened at the outer, and may be described as having four surfaces, of which the anterior and posterior are narrowed towards the outer end to margins, while the upper and lower surfaces are broadened at that part.

The *upper surface* is superficial, inclined forwards in its inner half, and the only muscular mark on it is near the inner end and posterior border, where the clavicular origin of the sterno-mastoid muscle is placed. The *posterior surface* is smooth in its inner and concave part, but externally

where it narrows to a border it is rough and gives insertion to the trapezius muscle. The *anterior surface*, in its narrow external part, gives attachment to the deltoid muscle, and more internally broadens into an area looking forwards and downwards, and affording origin to the upper part

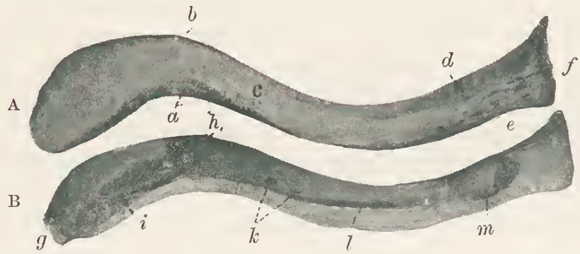


FIG. 139.—THE CLAVICLES. A, View from above of right clavicle: *a*, origin of deltoid muscle; *b*, margin giving insertion to trapezius; *c*, subcutaneous upper surface; *d*, smooth deep surface; *e*, origin of pectoralis major; *f*, clavicular origin of sterno-mastoid muscle. B, View from below of left clavicle: *g*, acromial surface; *h*, conoid tubercle; *i*, trapezoid ridge; *k*, arterial foramina; *l*, ridge of costo-coracoid membrane, with groove of subclavius muscle behind it; *m*, costo-clavicular impression.

of the pectoralis major. The *inferior surface* presents, near the outer end, a marked roughness for the two parts of the coraco-clavicular ligament. Beginning posteriorly in a prominence (the *conoid tubercle*) projecting backwards and giving attachment to the conoid part of the ligament, it is continued obliquely forwards and outwards as a *ridge* for the *trapezoid* part; near the sternal end the attachment of the costo-clavicular or rhomboid ligament is marked by an irregular and often depressed surface. Between these two ligamentous marks runs a longitudinal groove, from which the subclavius muscle arises, bounded in front by a ridge for the attachment of the costo-coracoid membrane. The *sternal end*, the stoutest part of the bone, is occupied by a large articular surface of somewhat variable curve, prolonged on to a prominent angle directed downwards and backwards, which is locked against the back of the articular surface of the manubrium when the shoulder is thrown backwards.

The clavicle has no continuous marrow cavity, but the cancellations in its centre are large, and on the posterior surface there are usually one or two arterial foramina. It is sometimes perforated near its upper and hinder border by a cutaneous nerve.

THE SCAPULA.

The scapula or shoulder-blade presents (1) an expanded *body*, with an articular *head* for the humerus at the outer angle; (2) projecting behind the body, a *spine* with a superficial margin prolonged into a flat process, the *acromion*, which articulates with the clavicle; (3) arising from the upper border, close to the head, an important projection, the *coracoid process*.

The *body* or blade is of a nearly triangular form, having three borders and an upper, a lower, and an outer angle, the outer supporting the head.

The *upper border* is the shortest, and springing from its outer part is the coracoid process, internal to which is the *suprascapular notch* converted by a ligamentous or sometimes a bony band into a foramen transmitting the suprascapular nerve, while the remainder of this border is a thin edge directed upwards as well as inwards, giving attachment to the omo-hyoid muscle. The *vertebral border*, the *base*, is the longest, and divisible into three parts, a short part opposite the spine, with a second part above, and a third and longer part below, both inclining outwards as they recede from the first. The uppermost part gives attachment to the levator anguli scapulae muscle, the short middle part to the rhomboideus minor, and the lowest part to the rhomboideus major. The *axillary border* is at the side of a stout bar descending from below the articular head; at its upper part it presents a well marked roughness about an inch long, where the long head of the triceps muscle is attached, and below this it is usually marked by one or more grooves, where the dorsal branch of the subscapular artery is in contact with it. The *anterior surface* or *venter scapulae* is for the greater part slightly hollowed to form the *subscapular fossa*, from which, as well as from the stout bar outside, as far as the axillary border, the subscapularis muscle takes origin, for the most part fleshily, but with tendons within it indicated by converging ridges. In front of the upper and lower angles are two small flat surfaces beyond the subscapular fossa, which, together with a narrow line running between them in front of the base, give attachment to the serratus magnus muscle. On the *posterior surface* or *dorsum scapulae*, above the spine, is the *supraspinous fossa*, filled by the supraspinatus muscle; while, below the spine the infraspinatus muscle occupies the greatest space, arising from what is properly called the *infraspinous fossa*; while external to it, on the thick bar at the axillary margin, is an elongated area with distinct

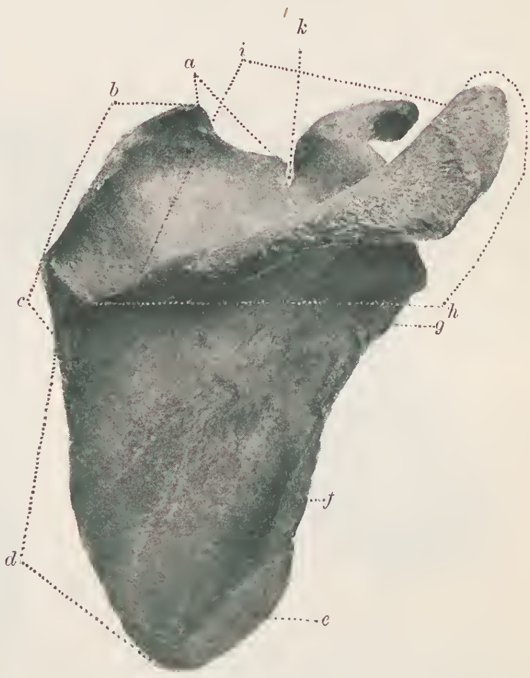


FIG. 140.—RIGHT SCAPULA FROM BEHIND. Attachments of muscles: *a*, omo-hyoid; *b*, levator anguli scapulae; *c*, rhomboideus minor; *d*, rhomboideus major; *e*, teres major; *f*, teres minor; *g*, long head of triceps; *h*, deltoid; *i*, trapezius; *k*, suprascapular notch.

boundaries indicating the origin of the teres minor, and below this a flat surface expanding behind the inferior angle, where the teres major takes origin.

The *spine* strikes backwards from the dorsum, arising by a line between the middle division of the vertebral border and a point separated by a broad groove from the back part of the articular head. From the outer end of this line a smooth concave border is directed backwards and upwards, while from the inner end there slopes a broad superficial border, more elevated as it extends outwards, till it arrives over the other, when both spread out and

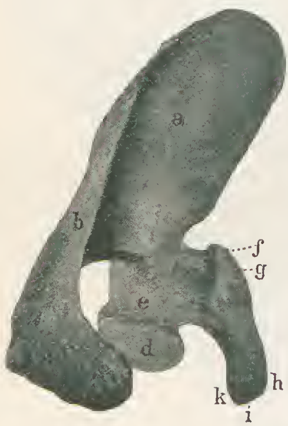


FIG. 141.—RIGHT SCAPULA FROM ABOVE. *a*, Supraspinal fossa; *b*, superficial margin of spine; *c*, acromion; *d*, glenoid fossa; *e*, neck; *f*, angle outside the suprascapular notch where the coracoid process changes its direction; *g*, rough attachment of coraco-clavicular ligament; *h*, insertion of pectoralis minor muscle; *k*, *i*, origins of coraco-brachialis and short head of biceps.

FIG. 142.—RIGHT SCAPULA FROM ANTERIOR AND OUTER SIDE. *a*, Notch of the glenoid fossa for reception of the small tuberosity of the humerus when the arm is raised.

become respectively the upper and under surfaces of a broad expansion called the *acromion*, which curves upwards and forwards on the top of the shoulder and bears on its inner edge, close to the tip, a small oval surface for articulation with the outer end of the clavicle. The superficial border of the spine begins at the base of the scapula by a smooth triangular area, over which glides the flat tendon of the lowest fasciculi of the trapezius muscle as it passes outwards to be inserted into a rough mark which lies across the border, beyond the triangular area. Outside this the upper edge of the superficial border of the spine and, continuous with it, the inner edge of the acromion are rough and give attachment all along to

the trapezius muscle, while the lower border of the spine, together with the outer edge of the acromion, gives origin to the deltoid muscle.

The *head* is the thickest part and supports a slightly concave articular surface called the *glenoid cavity*. This surface is pyriform, with the upper end narrow and inclined forwards so as to leave a notch in front. It fits the spherical curve of the head of the humerus, and is bevelled round the margin, giving attachment to the glenoid ligament which surrounds it. It is surmounted by a little tubercle from which the long head of the biceps muscle arises.

The *coracoid* process ascends vertically at its base from between the head and the suprascapular notch, but soon bends abruptly forwards with an outward inclination and a slight downward curve, projecting from under the outer end of the clavicle. On the posterior half of its upper surface is a thick tuberosity, giving attachment to the conoid and trapezoid ligaments, while from the margin of the tip spring the short head of the biceps muscle and the coraco-brachialis by a common origin, and more internally the tendon of the pectoralis minor muscle. The coracoid process, though only a portion of the scapula in the human subject, and reduced to much smaller proportions in many mammals, is the representative of a distinct element of the shoulder-girdle in monotremata and non-mammalian vertebrata.

The term *neck* is sometimes given to the constriction passing beneath the head and through the suprascapular notch, separating the head and the coracoid process from the rest of the bone. The neck is much more elongated and obvious in many mammals than in man.

The Humerus.

The humerus or arm-bone is thick and rounded above, slenderer below the middle, and flattened out distally into an *external* and *internal epicondyle*, surmounting the inferior articular extremity which is curved slightly forwards.

The upper extremity presents a *head* for articulation with the glenoid fossa of the scapula. This is large and rounded, forming less than a hemisphere, but, when coated with cartilage, accurately spherical in curve, except close to the margin below, where a narrow crescentic addition would be required. It looks upwards, inwards, and a little backwards, when the line joining the epicondyles is placed transversely. Immediately outside the head is the *great tuberosity*, in front the *small tuberosity*, and between the tuberosities the *bicipital groove*. The circle of depression round the head, passing between it and the tuberosities, is distinguished as the *anatomical neck*, while the part below the level of the tuberosities, where the upper extremity narrows to the shaft, is called the *surgical neck*, and is a frequent site of fracture. The great tuberosity is continued up from the shaft, bulging slightly outwards: it presents a facet looking upwards which gives attachment to the supraspinatus muscle; another, behind it,

looking upwards and backwards, on which is inserted the infraspinatus muscle; and a third, looking directly backwards, on which the teres minor is inserted. On the small tuberosity is inserted the subcapularis muscle.

From the front and inner side. From behind.

FIG. 143.—RIGHT HUMERUS.

On the shaft, for a fourth of its length, the *bicipital groove*, so named from lodging the long head of the biceps muscle, descends with a slightly inward inclination, bounded by an outer ridge which denotes the insertion of the pectoralis major muscle, and a less prominent inner ridge to which the teres major muscle is inserted, while the tendon of the latissimus dorsi

is attached to the rough lower part of the floor of the groove. Lower down and to the outside, looking forwards and outwards, is the *deltoid eminence*, a prominent roughness denoting the insertion of the deltoid muscle, bifurcated above and pointed below, reaching below the middle of the shaft, where it is sometimes so elevated as to give the bone the appearance of being bent. Looking forwards and inwards about the same level there is a slight linear roughness where the coraco-brachialis muscle is inserted, and just below it the *arterial foramen* sloping downwards into the bone and conveying the principal artery and vein of the marrow-cavity. The posterior border of the deltoid eminence is continued upwards towards the facet of the teres minor by a line from which the outer head of the triceps muscle arises, and it forms the anterior limit of the *musculo-spiral* groove, which twists from behind downwards and forwards and is limited below and behind by the external supracondylar ridge. This groove has resting on it the musculo-spiral nerve and superior profunda vessels, and is bare of muscular attachment in the length of its course, as is the inner and posterior surface with which it is continuous; but the upper part of the brachialis anticus muscle, which grasps the deltoid eminence with a bifid extremity, invades the lower and fore part of the groove, and the area so covered may be marked off from the rest by a line, and represents the much larger groove in many animals, which reaches up the whole length of the shaft, and is covered completely with brachialis anticus. The *external* and *internal supracondylar ridges* extend upwards from the two epicondyles, and separate, below the deltoid eminence, a flat posterior surface giving fleshy origin to the short head and deep part of the triceps muscle from an anterior surface covered by the brachialis anticus and divided into an outer and inner portion by a smooth elevation descending in continuity with the deltoid muscle. The external supracondylar ridge is the rougher and longer, and affords attachment, below the musculo-spiral groove, to the external intermuscular septum, and, in front of the septum, in its upper two-thirds to the supinator longus, and in its lower third to the extensor carpi radialis longior. To the internal supracondylar ridge is attached the internal intermuscular septum.

The lower extremity, when laid on a flat surface, causes the shaft to incline downwards and inwards by the prominence of the inner border of the articular surface. The *external epicondyle*, which gives attachment to extensor muscles of the forearm, descends lower than the internal, while the *internal epicondyle*, which gives attachment to flexor muscles, is more prominent laterally. The articular surface presents two parts, one for the radius and the other for the ulna. The radial surface is seen only from the front, and consists of a spherically curved eminence, the *capitellum*, and a groove separating it from the sharp margin of the ulnar surface. The ulnar surface, or *trochlea*, is in front internal to the radial surface, but is continued round, so as to be equally visible from behind, where it lies midway between the condyles and is broader. It is deeply grooved in its whole extent from

before backwards; its outer margin turns outwards behind the lower border of the radial surface, giving the additional breadth behind; and the lower part of the inner margin inclines inwards, giving the appearance to the trochlea of sloping downwards and inwards both in front and behind, though its groove is in the direction of the shaft. In front, above the capitellum, there is a depression which receives the head of the radius in flexion, and above the trochlea a larger depression into which, in flexion, the coronoid process of the ulna fits; while, behind, there is above the trochlea a deep fossa which receives the olecranon in extension. At the bottom of this fossa there is sometimes a perforation as in many other mammals; neither, however, in man nor in those animals does the olecranon fit into this perforation, but it presses against a point on the strong inner wall of the fossa where usually a mark can be seen indicating the precise spot.

Fig. 144.—Supracondylar Process on a left humerus.

The supracondylar process is an occasional hook-like process, not very uncommon, occurring in front of the internal supracondylar ridge, having a fibrous band extending from it to the internal epicondyle. Beneath the arch so formed the median nerve passes constantly, while the arterial relations vary (Struthers). In some animals, as the cat, a foramen occupies the same situation, and is traversed by the median nerve and brachial artery.

Fig. 145.—Sketch to show the Mechanism of Pronation and Supination. *a*, *b*, Olecranon and coronoid processes of the ulna; *c*, orbicular ligament grasping the head of the radius; *d*, triangular fibro-plate permitting the lower end of the radius to move in a semicircle round the ulna.

BONES OF THE FOREARM.

The forearm has two bones, the radius and ulna. The radius articulates with the humerus outside the ulna, and inferiorly is in contact with the hand over the *thenar* side, or side supporting the thumb, while the ulna lies over the little finger; and as, in anatomical description, the palm of the hand is said to be anterior, and the thumb and little finger are said to lie on the outer and inner sides, the radius is the outer bone of the forearm, the ulna the inner. The palm, however, is capable of *pronation* and *supination*, which means that it can be turned downwards or upwards by the lower end of the radius revolving in a semicircle round the ulna while the bent elbow is stationary; and the upward position of the palm in flexion of the elbow, or its anterior position when the forearm is pendent, is the extreme of supination. Semi-pronation, though not the position chosen for technical

anatomical description, is both the natural and the earliest position. In development, the palm looks inwards, with the thumb toward the head, and the head of the radius, not only in many mammals, but in all other vertebrates in which it exists, articulates with the humerus in front of the ulna. The external epicondyle of the humerus is developed overhanging the dorsum of the forearm, and the internal overhanging the ventral or flexor aspect, as they continue to do in semi-pronation.

The Radius.

The radius is much more slender above, where it is in comparatively limited contact with the humerus, than at its lower end, which is in extensive opposition with the carpus.

The head, or upper articular extremity, has a nearly circular upper surface, with a depression corresponding with the capitellum of the humerus, and a convex border which is broadest on the anterior and inner side, and fits, especially in semi-pronation, into the groove internal to the capitellum. The upper surface is continuous with a vertically-placed articular rim, deepest on the anterior and inner side, and rotating in a ring formed by the smaller sigmoid cavity of the ulna in conjunction with the orbicular ligament. The deepest part of the rim corresponds in semi-pronation with the smaller sigmoid cavity of the ulna; and the diameter of the head then thrown into the transverse position is slightly longer than the others.

The shaft is straight and cylindrical for a short distance above, forming the neck, then becomes three-sided, and at the same time becomes arched in the rest of its extent, with the convexity directed outwards and backwards. This arching is important surgically, since in fracture of the lower part of the radius it causes the broken ends to be displaced forwards. Opposite to where the arch begins is placed the large oval *bicipital tuberosity*, looking inwards and forwards, smooth on its summit, where a bursa is in contact with it, and rough along its posterior margin, where the tendon of the biceps muscle is inserted. Below this a sharp *internal border* separates the anterior from the posterior surface, and gives attachment to the interosseous membrane, while both surfaces are continuous on the outer side, by smooth borders with the external. The *external surface* is convex, and about the middle has a distinct roughness on it where the pronator radii teres muscle is inserted. On the *anterior surface* a smooth oblique ridge passes downwards and outwards from the lower end of the bicipital tuberosity, and separates a district extending down from the neck and giving attachment to the supinator brevis muscle from a longitudinal groove below and to the inside, whence arises the flexor longus pollicis; while from the ridge itself there springs the thin radial origin of the flexor sublimis digitorum. Below the oblique ridge the *arterial foramen* for the medullary vessels is situated, directed upwards into the bone. The broad lower part of the anterior surface is flattened from side to side and made concave by a prominent

inferior margin, externally distinct from the lower edge of the bone: it gives insertion to the pronator quadratus muscle. The *posterior surface* is marked toward the inside by two slight oblique depressions, the upper one reaching as high as the upper end of the roughness of the pronator radii

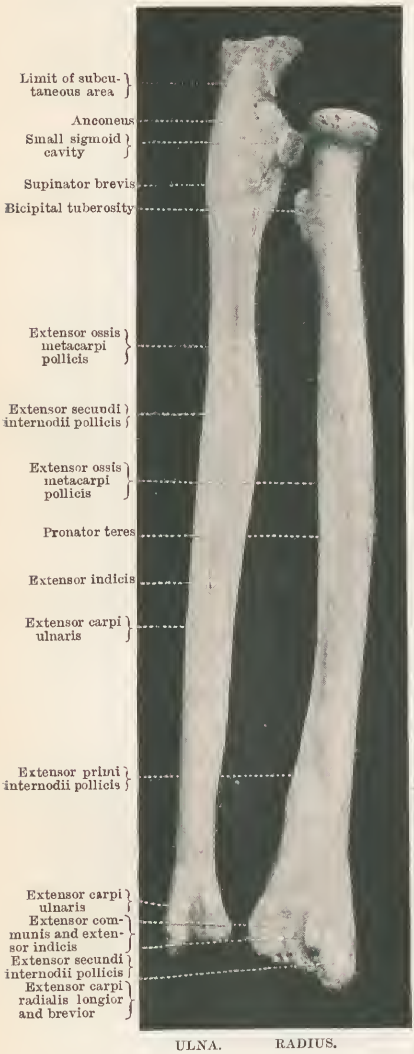


FIG. 146.—BONES OF RIGHT FOREARM from behind.

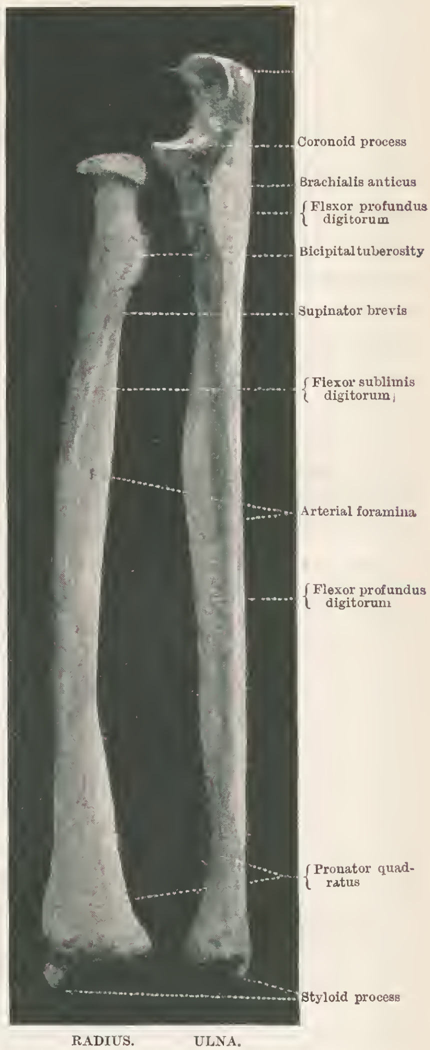


FIG. 147.—BONES OF RIGHT FOREARM from the front.

teres, and indicating the origin of the extensor ossis metacarpi pollicis, while from the other arises the extensor primi internodii pollicis.

The lower extremity of the radius is thickened from before backwards, and much expanded transversely. At the outside there projects downwards a stout projection, called *styloid process,* not from its shape

but simply from lying on the opposite side of the wrist from the styloid process of the ulna. Reaching outwards to near the extremity of this process, the inferior articular surface looks downwards and somewhat inwards, with an inclination forwards caused by the prolongation downwards of the posterior margin. It is pentagonal in form, and divided by a prominent line into an outer triangular part, which articulates with the scaphoid bone, and an inner quadrilateral part which articulates with the lunar bone. At its inner border it meets at right angles a surface looking inwards and concave from before backwards, which revolves on the ulna, and is separated from the radio-carpal joint in the recent state by a triangular fibro-plate, which leaves no mark on the macerated bone. Behind and on the outside, the lower end of the radius is marked by grooves in which tendons are lodged. On the outside of the styloid process there is one groove in which lie the extensors of the metacarpal bone and first phalanx of the thumb; it is surmounted by a roughness to which the supinator longus is attached. Behind there are two broad grooves, and between them a narrow groove directed downwards and outwards, with its outer margin always prominent and its inner margin variably developed. The narrow groove lodges the tendon of the extensor of the second phalanx of the thumb, while the outer broad groove is subdivided into an outer and inner part, lodging respectively the tendon of the extensor carpi radialis longior and that of the extensor carpi radialis brevior; and the other broad groove gives passage to the tendons of the extensor communis digitorum and extensor indicis muscles.

The Ulna.

The ulna is much more slender at its lower than at its upper end. It is longer than the radius, and passes up beyond it to fit its olecranon process into the corresponding fossa of the humerus.

The upper extremity presents two articular surfaces termed greater and smaller sigmoid cavities, and two projections, the olecranon and coronoid processes. The *great sigmoid cavity*, articulating with the humerus, looks forwards and is semicircular from above downwards, with a vertical ridge in its whole extent. It is constricted, and sometimes divided, in the middle, and above this it forms the front of the olecranon, while below it occupies the upper surface of the coronoid process. Internal to the ridge, it is transversely concave; while externally it is in its olecranal part bevelled, so as to present an elongated outer facet only used in approach to extension, and in its coronoid part is limited by the upper margin of the smaller sigmoid cavity. The *small sigmoid cavity* is on the outer side of the coronoid process, and is concave from before backwards, fitting against the vertical surface on the head of the radius. The *olecranon* has a rough upper surface, giving attachment to the triceps, and behind has a triangular subcutaneous surface continuous with the border which separates the posterior

from the inner surface of the shaft, while these two surfaces are prolonged up one on each side. The *coronoid process* presents inferiorly a rough tuberculated triangular area, into which the brachialis anticus muscle is inserted. Both the olecranon and the coronoid process are beaked in front, but the coronoid process projects rather further forwards than the olecranon.

The shaft deviates in its general direction about 10 degrees outwards from that of the trochlear ridge of the great sigmoid cavity. It is in the greater part of its extent three-sided and slightly curved, with the convexity backwards; but, for a short distance at the lower end, is straight, slender and cylindrical. The *outer border*, separating the anterior from the posterior surface and giving attachment to the interosseous membrane, is sharp in the greater part of its extent, but at the lower end is reduced to a mere line; while above, for about an inch below the smaller sigmoid cavity, it is replaced by a triangular area sufficiently depressed to leave room for the bicipital tuberosity of the radius passing it in pronation, at the same time that it gives origin all over to muscular fibres of the supinator brevis, and by the ridge behind it, to tendinous fibres of the same muscle. The *posterior border*, separating the posterior from the inner surface, descends from the subcutaneous triangular area of the olecranon, and is itself subcutaneous in its whole extent, the aponeurosis of the forearm being attached to it; but with regard to its position as seen during life, it is to be noted that while in semipronation it is sufficiently prominent to be used for leaning on, it is seen, during supination, nearly in the middle of the back view of the forearm, as a depressed line between the masses of flexor and extensor muscles descending from the two epicondyles of the humerus. The *internal border* is a smooth elevation descending from the tuberculated area of the brachialis anticus, and separating the anterior from the inner surface. The *anterior surface*, below the tuberculated area, is longitudinally grooved in more than half its extent, where it gives origin to muscular fibres of the flexor profundus digitorum muscle, and is perforated towards the upper part of the groove by the upwardly directed *arterial foramen* for the medullary vessels; while on its lower part it presents a slight depression, limited internally by a line, indicating the origin of the pronator quadratus muscle. The *internal surface* is smooth throughout, and in its upper two-thirds is somewhat concave, giving origin in continuity with the grooved part of the anterior surface to the flexor profundus digitorum muscle. The *posterior surface* presents above on the outside of the olecranon a triangular area on which the anconeus muscle is inserted, separated below by an oblique line from a longitudinal groove descending on the inner half of the surface against which the extensor carpi ulnaris rests; and external to this are three oblique grooves, the uppermost of which, lying below the ridge of the supinator brevis, indicates the origin of the extensor ossis metacarpi pollicis, while from the second the extensor secundi internodii pollicis takes rise, and from the lowest the extensor indicis.

The inferior extremity is but slightly expanded, and presents an articular surface divided into two parts; one of a circular form looking downwards, separated in the recent state from the cuneiform bone by the triangular fibro-plate; the other a convex rim looking outwards and forwards to articulate with the radius. Behind and internal to the articular surface descends the cylindrically-shaped *styloid process*, which gives attachment to the internal lateral ligament of the wrist-joint. Between it and the articular surface is the depression to which the triangular fibro-plate is attached, and behind there is a groove in which lies the extensor carpi ulnaris.

BONES OF THE HAND.

The Carpus.

The carpus consists of eight small bones arranged in two rows. Those of the upper row are named, from without inwards, scaphoid, lunar,

Fig. 148.—Right Hand, Palmar View.

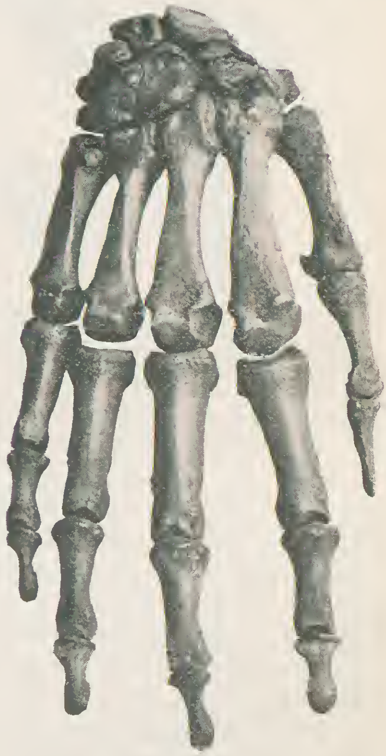


Fig. 149.—Right Hand, Dorsal View.

cuneiform and pisiform, and of these, the three first form a block which presents superiorly an articular surface convex from side to side as well as from before backwards, and looking upwards and backwards; while

inferiorly it presents another articular surface continuous all the way across, but abruptly convex at the radial side, deeply concave in the middle, and slightly bevelled internally. The pisiform is articulated in front of the cuneiform, and not in range with the other bones of the row.

The bones of the second row are named trapezium, trapezoid, os magnum and unciform; and of these the two inner, namely, the os magnum and unciform, fill up the concavity of the upper range, while the two outer, the trapezium and trapezoid, articulate with the convexity formed by downward projection of the outer part of the scaphoid.

The **scaphoid bone** presents superiorly a convex surface looking upwards and backwards to articulate with the triangular facet on the radius, and inferiorly a deep articular concavity looking downwards and inwards and resting on the os magnum. External to both of these surfaces the scaphoid

FIG. 150.—PALMAR VIEW OF RIGHT CARPAL BONES. *a*, Scaphoid ; *b*, semilunar ; *c*. cuneiform ; *d*, pisiform ; *e*, trapezium ; *f*, trapezoid ; *g*, os magnum ; *h*, unciform. ×, ×, ×, The tubercle of the scaphoid, ridge of the trapezium and unciform process of the unciform, which, together with the pisiform, give attachment to the anterior annular ligament.

is thickened and bent forwards as a tuberosity giving attachment to the anterior annular ligament. Beneath and behind the tuberosity is a convex articular surface continuous with that for the os magnum, and less abruptly distinguished from it behind than in front, articulating with the tapezium and tapezoid, and most thoroughly in contact with them when the wrist is over-extended. The inner side articulates with the lunar and is narrow from above downwards and inclined downwards and outwards. The anterior and posterior surfaces are non-articular, the anterior concave from side to side, the posterior narrow from above downwards and convex from side to side.[1]

The **lunar or semilunar bone** is named from its crescentic form as seen in profile. Both the outer and inner surface are inclined downwards and outwards and are flat. The outer surface is broader from before backwards

[1] A little ossicle beneath the inner and back part of the scaphoid was pointed out by Gruber as a not unfrequent anomaly, and represents the *os centrale* found in certain mammals.

than the inner, while the inner is the broader from above downwards. The upper and under surfaces are quadrilateral, the upper convex, the under concave from before backwards. Superiorly it articulates with the radius, externally with the scaphoid, internally with the cuneiform, and inferiorly with the os magnum, while the margin between the inferior and internal surfaces is flattened into a narrow surface which comes in contact with the unciform bone. The anterior surface is larger both transversely and vertically than the posterior.

The **cuneiform** or **pyramidal bone**, presents a flat articular surface externally, corresponding with the inner surface of the lunar bone, while internally it is rough, rounded and smaller. Its inferior surface is articular in its whole extent, resting in contact with the unciform bone, while, on the superior surface there is a smaller convex articular surface extending inwards a variable distance from the edge of contact with the lunar bone,

Fig. 151.—Dorsal View of Right Carpal Bones. *a*, Scaphoid ; *b*, semilunar ; *c*, cuneiform ; *d*, pisiform ; *e*, trapezium ; *f*, trapezoid ; *g*, os magnum ; *h*, unciform.

to glide against the triangular fibro-plate. The anterior surface is specially distinguished from the posterior by a flat circular articular surface on its inner half for the pisiform bone.

The **pisiform bone**, as its name implies, is a rounded body like a pea. It has only one articular surface, which corresponds with that on the front of the cuneiform bone, and from this it droops a little in a downward and outward direction. It gives attachment above to the flexor carpi ulnaris, below to two ligaments extending to the unciform and fifth metacarpal bones, and externally to the anterior annular ligament.

The **trapezium** supports the metacarpal bone of the thumb, and articulates with it by a large saddle-shaped surface, concave from side to side and convex from before backwards, looking downwards and outwards. Anteriorly, it presents a prominent ridge for attachment of the anterior annular ligament, and, internal to this, a deep groove occupied by the tendon of the flexor carpi radialis muscle. The posterior surface is broad, and, as well as the anterior and outer surfaces, is non-articular. The inner

surface is much deeper than the outer, and in its upper half articulates from front to back with the trapezoid, while beneath this it has a facet posteriorly for the second metacarpal bone, in front of which it is rough and curves outwards into the anterior surface. The superior aspect is the smallest of all and has a slightly concave articular surface for the scaphoid bone.

The **trapezoid** is, next to the pisiform, the smallest bone of the carpus. Its longest diameter is from its anterior to its posterior free surface; and of these the posterior is much the larger, though variable in size. The roughness of the anterior surface is prolonged backwards for some distance at the lower and outer angle, where it helps to bound the interval between the bases of the first and second metacarpal bones. The inferior articular surface is the broadest, and convex from side to side, supporting the second metacarpal bone. The external and internal surfaces articulate with the trapezium and os magnum respectively, while the superior is narrower and articulates with the scaphoid. Between the internal and inferior surfaces, in the posterior part of their extent, an angular facet is intercalated, which articulates with the third metacarpal bone.

The **os magnum** is the largest of the carpal bones. It is surmounted by a *head*, the rounded articular summit of which is prolonged over the back of the bone so as to look nearly as much backwards as upwards, and is carried still further down on the outer side; and the whole convexity is divided by a slight line into two parts, articulating with the scaphoid and lunar bones respectively. On the inner side is a flat articular surface extending from summit to base, interrupted by a rough mark for an interosseous ligament, and fitting against the unciform bone. On the outside, below the surface for the scaphoid, it articulates by a short flat surface with the trapezoid bone. The base, which is horizontal in front and looks downwards and outwards behind, corresponds mainly with the base of the third metacarpal bone, but posteriorly comes in contact also with the fourth. The non-articular anterior surface extends from summit to base, while the posterior is cut short above by the articular head, and is much broader.

The **unciform bone** is next in size to the os magnum, and is named from a great curved process which, projecting from the inner part of its anterior surface, gives attachment to the anterior annular ligament. The outer surface of the bone is elongated and flat, corresponding with the inner surface of the os magnum, while the base is divided by a line into two facets supporting the fourth and fifth metacarpal bones. The inner surface is short and rough. The upper surface is articular, looking upwards and inwards, and in more than half its extent from the outer end is convex with an inclination backwards, while in the remainder it is concave and inclined forwards; it comes mainly in contact with the cuneiform bone, but, close to the os magnum, articulates also with the lunar bone.

The Metacarpus.

The metacarpal bones are five in number, supporting the digits. Each has a base, a slightly curved shaft, and a distal extremity or head convex from side to side as well as from dorsum to palm, and prolonged furthest up on the palmar aspect. The first metacarpal bone, that of the thumb, requires separate description. The other four decrease regularly in size from the second to the fifth, and while differing considerably at their bases, have the following characters of shaft and head.

The *shafts* of the four inner metacarpals expand gradually from immediately beyond the base, and present dorsally a flat triangular surface which extends up from the head and is prolonged at its apex by a ridge separating lateral surfaces. These latter give attachment to muscles, and meet on the palmar aspect in a ridge on the distal half of the shaft.

The *head* of each of the four inner metacarpals presents an articular surface increasing in breadth from behind forwards. It has beneath it, in front, a depression to receive the first phalanx in flexion, and on the sides of this has prolongations which never come into contact with the phalanx. The angles at the base of the triangular area at the back of the shaft project laterally as *tubercles* close to the head, which, together with depressions in front of them, give attachment to the lateral ligaments.

The *bases* of the four inner metacarpal bones have characteristic features distinguishing them one from another. The base of the *second* has its upper surface grooved to fit on to the trapezoid, and has two lateral projections upwards, the outer of which is seen only behind, and bears a lateral facet for articulation with the trapezium, while the inner articulates laterally with the third metacarpal bone all the way forwards, and comes in contact with the os magnum in front. The base of the *third* metacarpal presents at its posterior and outer angle an upward projection or *styloid process*, ascending beyond the adjacent prominence of the second; it articulates above with the os magnum, and at each side with the adjacent metacarpals, while on the outer side of the styloid process it has an angular facet for the trapezoid. The *fourth* metacarpal articulates at its sides with the third and fifth, while its upper surface inclines very slightly inwards and articulates mainly with the unciform bone, but also by a small facet behind and to the outer side with the os magnum. The *fifth* metacarpal articulates above with the unciform bone, externally with the fourth metacarpal, and has a free rough surface internally, giving attachment to the tendon of the extensor carpi ulnaris.

The *first metacarpal bone* is shorter and broader than any of the others. Its shaft is somewhat flattened from before backwards, presenting posteriorly a uniform surface bounded by lateral ridges in front of which is the anterior surface, which is divided by a smooth elevation into a broader outer part on which the opponens pollicis is inserted, and a narrower inner part giving

origin to the abductor indicis. The base presents a saddle-shaped surface convex from side to side, and concave from before backwards for articulation with the trapezium.

The Phalanges.

The phalanges are fourteen in number, three for each finger and two for the thumb. They are everywhere broader from side to side than from before backwards.

The five *proximal* or *metacarpal* phalanges are thickest at their bases, which articulate each by a shallow concave surface with the metacarpal bone which supports it. The shaft of each has an anterior surface longitudinally concave, flat from side to side, and separated by rough lateral ridges for the sheaths of the flexor tendons from the posterior surface, which is convex in both directions and smooth. The distal end, scarcely wider than the shaft, has a convex articular surface with a trochlear groove.

The *intermediate* four phalanges, or second row of the fingers, are immediately distinguished from proximal phalanges by the presence of a little antero-posterior ridge on the basal articular surface, separating two slight concavities and fitting into the trochlear groove on the phalanx above.

The *distal*, *ungual* or *terminal* phalanges have basal articular surfaces similar to intermediate phalanges of the fingers. Beyond the base they suddenly narrow, and they are crowned by a rough ridge at the free end. Posteriorly they are smooth, but in front present two roughnesses, one continuous with the terminal ridge, the other in front of the base and giving attachment to a flexor tendon.

The phalanges of the middle finger are longer than those of the other three; those of the forefinger are shorter than those of the ring finger. The distal phalanx of the thumb is the largest of all the distal phalanges, and its proximal phalanx is distinguished by its breadth.

A pair of *sesamoid bones* is found on the flexor side of the metacarpo-phalangeal joint of the thumb, and occasionally others occur in the corresponding joint of one or more of the other digits.

ARTICULATIONS OF THE UPPER LIMB.

The Shoulder-Girdle.

The sterno-clavicular articulation has two synovial cavities separated by an interarticular fibro-plate, and is surrounded by a dense capsule whose fibres are directed upwards and outwards; those in front and behind being termed the *anterior* and *posterior ligaments*, while two additional bands, the interclavicular and the costo-clavicular, strengthen it on the inner and outer aspects.

The interclavicular ligament consists of fibres associated with the capsule,

and extends from one clavicle to the other, uniting their upper borders and adherent to the interclavicular notch between.

The costo-clavicular or *rhomboid ligament* is very strong, extending outwards for as much as an inch in continuity with the posterior ligament, but leaving between it and the anterior ligament a recess opposite which the capsule is weak. It is attached inferiorly to the first costal cartilage and superiorly to the roughness on the under surface of the clavicle. Externally its fibres are in series with those of the subclavius muscle, and of the costo-coracoid membrane covering that muscle. In connection with it there is often a costo-clavicular synovial bursa.

The interarticular fibro-plate forms a disc strong at the circumference, though sometimes perforated in the middle. It is connected in front and

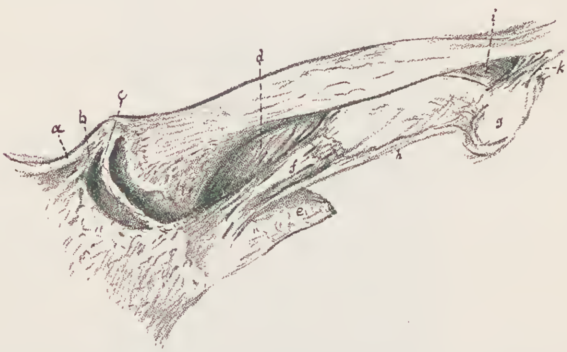


FIG. 152.—LEFT STERNO-CLAVICULAR AND STERNO-ACROMIAL ARTICULATIONS. *a*, Interclavicular ligament; *b*, superior sterno-clavicular ligament; *c*, fibro-plate; *d*, costo-clavicular ligament; *e*, first rib; *f*, tendon of subclavius muscle; *g*, coracoid process; *h*, band of costo-coracoid membrane, sometimes called ligament; *i*, conoid ligament; *k*, trapezoid ligament.

behind with the capsule of the joint, while at its upper part it is firmly attached to the clavicle, and at its lower to the concavity of the articular surface of the sternum.

The outer synovial cavity, between the fibro-plate and the clavicle, extends further down than the inner, so as, at its lower part, especially on the deep side, to reach even to the sternum beyond the insertion of the fibro-plate. *The inner synovial cavity* stretches higher up than the outer, but is less extensive.

The acromio-clavicular articulation, in which the oval articular surfaces of the clavicle and acromion take part, is surrounded by a fibrous capsule, forming a strong *superior* and a thin *inferior ligament.* The synovial membrane is very redundant, invading the surfaces of the articular cartilages, and projecting in thick fringes between them.

The coraco-clavicular articulation is imperfect, consisting of a *coraco-clavicular ligament* divisible into two parts, called conoid and trapezoid. The *conoid ligament*, the posterior and inner part, stretches from the conoid tubercle of the clavicle down to the back part of the tuberosity of the

coracoid process, and, as seen from in front or behind, is broad above and narrow below. The trapezoid ligament has its fibres parallel, directed from the trapezoid ridge of the clavicle downwards and inwards to the tuberosity of the coracoid process, its posterior border in contact with the outer border of the conoid ligament; and in the recess between the two there is often a synovial bursa.

Ligaments of the scapula. *The coraco-acromial* or *deltoid ligament* is the more important of these. Its attachment to the acromion is narrow and placed on the inner side of the tip; its other attachment extends along the outer edge of the coracoid process. Its anterior and posterior fibres are strong, while between them there is a weak part or a gap. It completes with the acromion an arch separated by a bursa from the humerus and the insertion of the supraspinatus muscle, which are pushed up against it when the arm is leaned on.

The suprascapular ligament is the band of fibres which converts the suprascapular notch into a foramen.

Movements of the shoulder-girdle. The clavicle admits of movement on the sternum in upward, downward, forward and backward directions. Its elevation is limited by the costo-clavicular ligament, which is tightened when the arm is raised. When the arm is depressed, as in lifting a heavy weight, the interclavicular ligament and interarticular fibro-plate are tightened by the rolling upwards of the inner end of the clavicle round the attachments of the anterior and posterior ligaments, while the shaft is dragged downward and forward, gliding on the first costal cartilage. Thus the greatest depression of the clavicle involves a forward position of the shoulder. But when the outer end of the clavicle is raised, it can be moved forwards and backwards. The coraco-acromial joint allows movement in every direction, so far as its own structure is concerned, but is limited in its actual movements by the coraco-clavicular ligament and the wall of the thorax. The coraco-clavicular ligament limits movement of the lower angle of the scapula outwards, and movement of the base both backwards and forwards. In shrugging the shoulder the base of the scapula is approached to the clavicle; in letting it fall by its own weight, especially when the vertebral column is erect, the angle between scapula and clavicle is enlarged. When the arm is raised, the lower angle of the scapula is carried outwards, the elevation of the arm being accomplished by movement of the shoulder-girdle, as well as of the humerus on the scapula, and the movements of the girdle being effected in part at the sterno-clavicular articulation, and in part at the acromio-clavicular.

The Shoulder-Joint.

This is a true ball-and-socket joint, the surfaces being perfectly spherical, with the exception that the head of the humerus requires to be very slightly raised close to its margin internally. The large amount of variety of movement which it allows is obtained by the small size of the scapular

articular surface as compared with the humeral, together with looseness of capsule, and thus it is more liable than other joints to dislocation. The tendon of the long head of the biceps muscle traverses the joint, covered by a sheath of synovial membrane.

The glenoid ligament is a fibrous rim surrounding the glenoid cavity, which, taking origin from the bevelled margin all round, has its fibres matted and forms a yielding addition to the articular surface. At the upper end it is continuous with the tendon of the long head of the biceps muscle, which takes origin partly from its fibres and partly from the tubercle above the glenoid cavity.

The fibrous capsule (*capsular ligament*) is weak, and is loose to such a degree that, when the muscles have been dissected away, the head of the

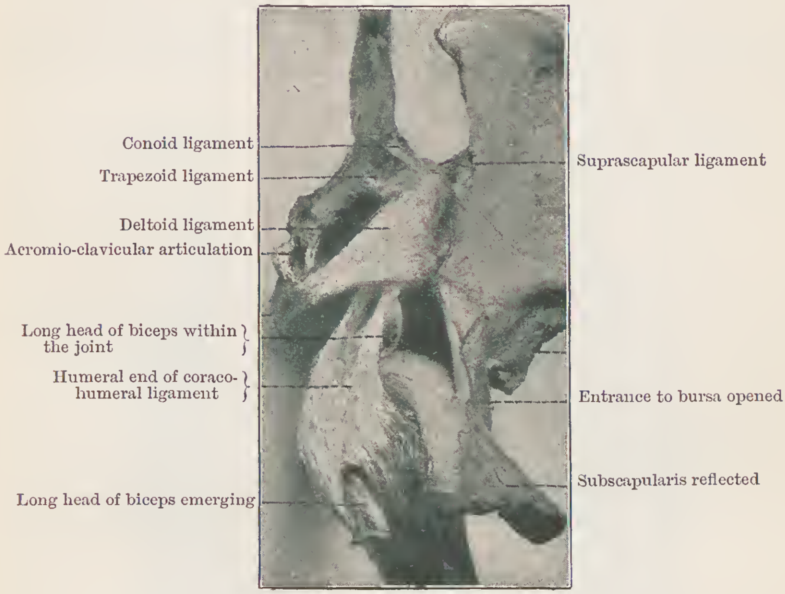


FIG. 153.—RIGHT SHOULDER.

humerus, being allowed to hang, will separate as much as three-quarters of an inch from the glenoid surface. The fibres are shortest and strongest above, where they are attached close to the tuberosities, and are longest below, where they descend on the inner side of the humerus for about half an inch below the articular cartilage. They come from the margin of the head of the scapula, with the exception of an accessory band of fibres springing beneath the deltoid ligament from the coracoid process, the *coraco-humeral ligament.* Above and behind, the capsule is strengthened by the supraspinatus, infraspinatus and teres minor muscles, while inferiorly it has no muscular support, and in front it is in peculiar relation to the tendon of the subscapularis muscle, which, instead of supporting it, enters into its

formation, being separated from the head of the scapula by only a bursal prolongation of the synovial membrane, so that it may be said to perforate the capsule. Another perforation exists between the greater and smaller tuberosity, where the upper part of the bicipital groove is converted by short transverse fibres into a canal for the passage of the tendon of the long head of the biceps muscle.[1]

The synovial membrane lines the capsule, and is reflected to the margins of the articular cartilages, covering the periosteum within the capsule on the inner side of the humerus. It clothes the glenoid ligament and extends as a cylindrical investment over the tendons of the biceps.[2] When this tendon is pulled on, so as to place the scapula as in elevation of the arm, the lower end of this cylinder is drawn down beyond the capsule, and a loose continuation of it is reflected up to the opening by which it is protruded, but incloses an additional extent of the tendon when the humerus is depressed. Another complication is found underneath the subscapularis muscle where a bursa communicating with the neck by a wide or narrow opening lies in front of the neck of the scapula.

Movements of shoulder-joint. Although the capsule appears to be so loose, its lower fibres are stretched in extreme elevation of the humerus, the hinder fibres when the arm is flung across the chest, and the anterior fibres when the arm is thrown backwards; and in these positions the glenoid ligament fits into the margin of the head of the humerus. To stretch the upper fibres requires further adduction of the humeral shaft than mere contact with the side of the body; but it can be obtained by throwing back the vertebral column and folding the arms across the chest; but even when the upper part of the capsule is stretched, the glenoid ligament is not pressing very closely against the inner part of the humeral neck. When the humerus is raised till the glenoid margin is locked against it, the shaft lies at right angles to the base of the scapula, when the anterior aspect is rotated upward so as to supinate the palm, and falls a little short of that amount of elevation, if the palm be pronated. When the scapula is made to move on the humerus by pulling on the long head of the biceps muscle, the glenoid tubercle is fitted into the upper end of the bicipital groove, and special stability of position is obtained. This is the position when pushing directly outwards. A position of still greater stability is got by pulling on both heads of the biceps muscle so as to throw the bones into the position which they occupy when one pushes in an outward and forward direction; the top of the smaller tuberosity being then fitted exactly into the notch in the front of the glenoid fossa. But

[1] The fibres bounding the opening for the subscapularis above and below, and those inserted between the subscapularis and teres minor muscles on the inside of the humerus, have been described as three *gleno-humeral* ligaments or folds, but have no claim to separate description.

[2] In some mammals the tendon of the biceps is superficial to the joint, *e.g.* in the horse; in rodents it is in contact with the synovial membrane but not surrounded, and in the adult sheep it has a short mesotendon (Welcker, Debierre).

in the positions in which pressure is perhaps most frequently made on the humerus, its head is pressed not against the glenoid surface but against the coraco-acromial arch, between which and the muscle clothing the joint there is a large sub-acromial bursa. Observation on the living subject shows that in raising the arm it is not the case that the elevation at the shoulder-joint is completed first, and then followed by movements of the shoulder-girdle. The elevation of the shoulder-girdle always begins before elevation at the shoulder-joint is completed, but the mode in which the two movements are mixed differs in different persons. The amount of rotation of the humerus allowed is about quarter of a circle, both in the raised and hanging condition.

The Radio-Ulnar and Elbow-Joints.

The radius and ulna are articulated one with the other by means of a superior and an inferior articulation and ligamentous union between. But the superior radio-ulnar articulation is inseparably connected with the elbow-joint and may be described along with it.

The elbow-joint. *The orbicular* or *annular ligament* is a strong band attached in front of and behind the small sigmoid cavity of the ulna, and

Fig. 154.—Extended Right Elbow-Joint from the front. *a*, Anterior ligament, the inner part of the ligament removed so as to indicate the coronoid fossa; *b*, external lateral ligament; *c*, orbicular ligament; *d*, tendon of biceps, with the bursa between it and the bicipital tuberosity.

Fig. 155.—Extended Right Elbow-Joint from behind. *a*, External lateral ligament; *b*, orbicular ligament; *c*, gap between humerus and radius; *d*, oblique radio-ulnar ligament.

forming together with it a complete ring embracing the head of the radius.

The external lateral ligament is a flat band attached superiorly below the external epicondyle of the humerus and inferiorly to the orbicular ligament.

The internal lateral ligament arises from below and from behind the internal epicondyle of the humerus and its fibres spread out to be inserted along the inner edge of the great sigmoid cavity of the ulna, from its olecranal to its coronoid extremity.

The anterior and posterior ligaments are membranous, and though they complete the fibrous capsule of the elbow-joint, they have no share in determining its movements. The anterior ligament consists of vertical fibres descending from above the coronoid and radial depressions of the humerus to the coronoid process of the ulna and the orbicular ligament. The posterior ligament consists of fibres which arise from the sides of the olecranon fossa of the humerus and are attached mostly to the olecranon process; but the uppermost of them arch across continuously, leaving above them a deficiency in the fibrous capsule, where the olecranon fits into the fossa of the humerus in extension.

FIG. 156.—FLEXED RIGHT ELBOW-JOINT from behind. *a*, Posterior ligament; *b*, internal lateral ligament; *c*, point of contact of capitellum and radius.

The synovial membrane lines the capsule and is prolonged up over the fossae of the humerus, in the neighbourhood of which, especially of the olecranon fossa, it is thickened and exhibits pads of fat. It is also prolonged on the inside of the orbicular ligament and is loosely reflected below it, so as not to interfere with pronation and supination.

The ligamentous union of the shafts of the radius and ulna is effected by two structures:—

The interosseous membrane consists of fibres directed obliquely downwards and inwards between the sharp adjacent borders of the radius and ulna, beginning a little below the bicipital tuberosity, and inferiorly lying well back between the bones as far as the lower articulation.

The oblique ligament is a little band of fibres, not always present, which descends from the outer and lower border of the rough surface beneath the coronoid process of the ulna, and is attached to the inner border of the radius a little below the bicipital tuberosity.

The inferior radio-ulnar articulation is a joint in which the lower articular surface of the ulna is opposed in its vertical part to the concave articular surface on the inside of the lower end of the radius, and in its terminal part to a triangular fibro-plate.

The triangular fibro-plate, or so-called *fibro-cartilage*, is attached by its base to the rectangular border separating the carpal surface of the radius from the ulnar surface, and by its apex to the ulna at the base of its styloid process. *The synovial membrane and fibrous capsule* are exceedingly loose, so as not to interfere with pronation or supination.

Movements of elbow-joint and forearm. The movement of the ulna on the humerus is hinge-like, consisting of flexion and extension in one plane. This plane coincides with that in which the shaft of the humerus lies, as may be proved by piercing the ulna with a pin in such a way that its point will slightly project and scratch the trochlea of the humerus when the joint is flexed and extended. The curves of such scratches are circular, and there is thus perfect conformity of the humeral and ulnar surfaces; but the inner part of the coronoid portion of the ulnar surface, and the bevelled part on the outside of its olecranal portion, only glide into contact with the humerus on approach to extension. In extension of the arm the shaft of the ulna is inclined about 10° outwards from the direction of the shaft of the humerus, so as to make an angle of about 170° with it; and consequently, when the arm hangs by the side, with the palm of the hand looking forwards, there is an angle pointing inwards at the level of the elbow; but pronation brings humerus and forearm into one straight line. The movement of the radius on the ulna is such that its shaft moves in the surface of a cone, the head being rotated within the grasp of the orbicular ligament, and the lower end circumducted round the insertion of the triangular fibro-plate. The apex of the cone is a little lower than the upper surface of the head, a slight shifting of the centre of rotation being caused by the turning inwards of the thick part of the convex border in pronation.

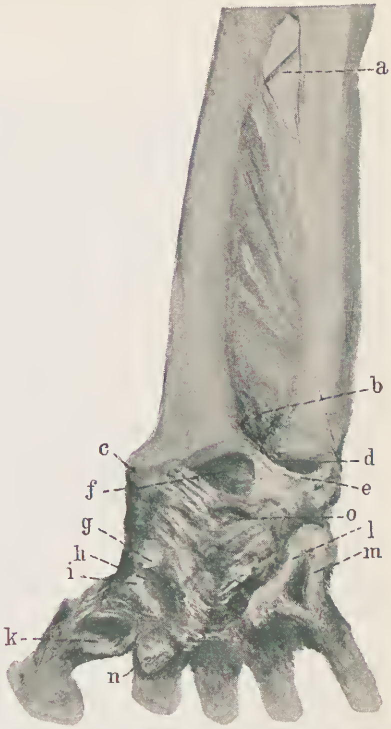


FIG. 157.—INTEROSSEOUS MEMBRANE AND CARPAL LIGAMENTS from the front, with complete over-extension of the wrist. *a*, Oblique ligament; *b*, recess formed by the interosseous ligament being attached inferiorly above the posterior margin of the radial surface for articulation with the ulna; *c*, styloid process of radius; *d*, inferior surface of ulna; *e*, triangular fibro-plate; *f*, upper surface of semilunar; *g*, tubercle of scaphoid; *h*, groove on trapezium for flexor carpi radialis; *i*, ridge of trapezium; *k*, articular surface of first metacarpal separated in its palmar part from trapezial surface by over-extension of the joint; *l*, *m*, descending ligaments of the pisiform, *l*, to the unciform process, *m*, to the fifth metacarpal; *n*, insertion of flexor carpi radialis into second metacarpal; *o*, the head of the os magnum. The pennate fibres in front of the carpus are the anterior radio-carpal and anterior common carpal ligaments.

In passing from extreme pronation to extreme supination, or the reverse, the lower end of the radius describes a semicircle, as may be seen by semiflexing the elbow, when it will be found that either the palm or back of the hand can be turned upwards. When the elbow is extended and the arm hanging, the hand can be rotated three-quarters of a circle, so that the palm can be turned outwards by continuation of rotation inwards;

but the additional quarter-circle is obtained from the shoulder-joint.[1] Owing to the capitellum looking forwards, the head of the radius begins to glide away from the humerus as soon as the elbow is extended beyond rectangular flexion; and in complete extension only its edge remains in contact, while a large angular gap is left behind to be filled with synovial membrane. The radius, therefore, is more advantageously placed to resist pressure when the elbow is somewhat flexed. It is most thoroughly in contact with the humerus when it is partially pronated, and the elbow is bent to a right angle.

The Joints of the Wrist and Hand.

The radio-carpal articulation, or wrist-joint, presents a superior articular surface, concave from side to side and from before backwards, divided into three facets, the outer two on the radius, and the inner formed by the triangular fibro-plate; while inferiorly a corresponding convex surface is formed by the upper surfaces of the scaphoid, lunar and cuneiform bones, united by an *external* and an *internal lunar interosseous ligament.* The ligaments thus named extend the whole distance from behind forwards between the upper lateral borders of the lunar bone and the opposed borders of the scaphoid and cuneiform bones respectively, and are lined above by the radio-carpal synovial membrane, and below by the synovial membrane of the common carpal articulation. Strong *internal* and *external lateral ligaments* descend from the styloid processes of the ulna and radius respectively to be inserted into the cuneiform and scaphoid bones. The *posterior ligament* or back part of the fibrous capsule has its fibres directed obliquely downwards and inwards; while the fibres of the *anterior ligament* or fore part of the capsule converge pennately to the lunar bone from the radius and the triangular fibro-plate.

Fig. 158.—Radio-Carpal and Common Carpal Articulation laid open from behind. *a*, Lower end of ulna clothed with sacciform capsule as it is seen in pronation; *b*, ridge on radius outside the oblique groove for extensor secundi internodii pollicis; *c*, triangular fibro-plate; *d*, scaphoid portion of the inferior surface of the radius, separated, in this specimen, from the lunar surface by a synovial fringe; *e*, lunar; *f*, head of os magnum; *g*, carpo-metacarpal joint of thumb.

The carpal, carpo-metacarpal and intermetacarpal joints have one synovial cavity common to them, with the exception that there is a

[1] In watching natural pronation and supination in the living body, it may be noticed that the ulna moves as well as the radius, as if the axis of the revolution were between the two; but careful study shows that this appearance depends on a slight rotation of the humerus, and if the humerus be well crushed up to keep it from turning, the lower end of the ulna remains stationary in pronation and supination. It is alleged by some that a slight lateral movement of the ulna is allowed, but this is certainly a mistake.

separate synovial sac for the articulation of the first metacarpal bone with the trapezium, and that there may be a separate sac for that of the cuneiform with the pisiform.

The articulation of the pisiform with the cuneiform is usually described as having a separate synovial membrane; but perhaps is as often found communicating with the cavity of the radio-carpal articulation. Two *descending ligaments* pass from the pisiform bone to the base of the fifth metacarpal and the unciform process of the unciform bone, and bear the strain of the tendon of the flexor carpi ulnaris.

FIG. 159.—LIGAMENTS OF BACK OF HAND. *a*, Posterior radio-carpal ligament; *b*, posterior common carpal ligament, extending from the cuneiform partly to the scaphoid and partly to the trapezoid and second metacarpal; *c*, external lateral ligament of the common carpal joint; *d*, internal metacarpal ligament of thumb, and, above it, the posterior band of the carpo-metacarpal joint of thumb; *e*, *f*, insertions of tendons of long and short radial extensors of carpus; *g*, synovial membrane stretched by flexion of third metacarpo-phalangeal joint; *h*, external lateral ligament of second metacarpo-phalangeal joint; *i*, space between knuckle and extended phalanx.

The articulation of the trapezium with the first metacarpal bone is always distinct, and surrounded with a fibrous capsule, in connection with which three ligamentous bands may be described, two of them, a palmar and a dorsal, being parts of the capsular wall uniting the first metacarpal to the trapezium, the dorsal band, the stronger and broader of the two, while the third is a distinct ligament at right angles to both of them, extending forwards from the base of the second metacarpal to the inner side of the palmar prominence at the base of the first metacarpal, and seems to have escaped notice. It may be termed the *internal metacarpal ligament of the thumb.*

The ligaments of the first range of carpal bones, uniting the scaphoid and cuneiform to the lunar, are the *external* and *internal lunar interosseous*, already described with the radio-carpal joint, and *dorsal* and *palmar bands.*

The ligaments of the second range are *dorsal, palmar and interosseous*; but the interosseous differ from those of the first range in being rounded bundles which allow the synovial membrane to pass them. There is

always an interosseous ligament between the os magnum and unciform, and another between trapezium and trapezoid, but that between os magnum and trapezoid is inconstant.

The common carpal ligaments uniting the two ranges are *dorsal*, *palmar* and *lateral* parts of a fibrous capsule. The dorsal ligament has its fibres principally directed with an obliquity downwards and outwards, the reverse of that of the dorsal ligament of the joint above, while the palmar ligament has its fibres pennate, in continuity with that of the joint above. The external lateral fibres unite the scaphoid with the trapezium, the internal lateral fibres unite the cuneiform with the unciform.

The ligaments uniting the lower carpals and *four inner metacarpals* comprise dorsal and palmar bands, the dorsal much more distinctly separate than the palmar. A constant ligament extends directly outwards from the bases of the second and third metacarpals to the inner and lower angle of the trapezium (Bruce Young).

The bases of the four inner metacarpals are firmly united by *dorsal*, *palmar* and *interosseous ligaments*, the latter not only projecting into the synovial cavity, but extending below it.

The anterior annular ligament is a very strong structure, stretching from the tubercle of the scaphoid and front of the trapezium to the pisiform bone and the process of the unciform bone. Its attachment to the trapezium is principally connected with the ridge, but it also takes origin from near the inner border, so as to convert the groove of the trapezium into a tubular passage for the tendon of the flexor carpi radialis. It completes the concavity of the carpus into a ring. It is called anterior annular ligament, in contradistinction to the posterior, which is described with the aponeurosis of the limb.

The metacarpo-phalangeal articulations are kept together by lateral ligaments. Posteriorly they are devoid of ligaments, their synovial membrane being protected by extensor tendon; and anteriorly, though they present a thick fibrous wall, it is not attached to the metacarpal bone.

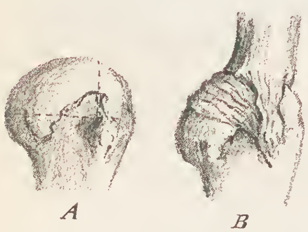


FIG. 160. — METACARPO-PHALANGEAL ARTICULATION. *A*, Shows by means of two dotted lines, extending from the place of attachment of the lateral ligament, that the ligament has a greater distance to pass over in flexion than in extension. *B*, Shows the slackened condition of the lateral ligament in extension, and the fibres arching over the front of the head of the metacarpal bone.

The lateral ligaments spring from the tubercles of the metacarpal bones and the depressions in front of them. Their posterior fibres pass to the sides of the phalanges; while those further forwards are attached more to the palmar aspect, and the foremost fibres of each turn forwards over the front of the metacarpal head to be continuous with corresponding fibres from the other side, forming a dense wall adherent to the base of the phalanx and with an edge which fits against the metacarpal bone in flexion.

The interphalangeal articulations have strong lateral ligaments and are covered behind by the extensor tendons, in front by the thecae of the flexor tendons.

Movements of wrist and hand. The radio-carpal articulation admits principally of flexion and extension, but also allows a notable amount of lateral flexion. Adduction or inward flexion is allowed to a much greater extent than abduction or outward flexion, and the total amount of lateral movement varies in different persons. In lateral flexion the scaphoid, lunar and cuneïform bones so move that each presses only on the facet ordinarily opposed to it. In complete over-extension, which is the position of the joint when the hand is leaned on, the edge of the radius fits into the back of the lunar and scaphoid. In the course of over-extension the radius presses the lunar forwards between the scaphoid and cuneiform, and when the movement is completed, the joint between the two ranges of carpal bones being likewise over-extended, the lunar is kept in its place by tension of ligaments. When these ligaments are ruptured dislocation of the lunar bone forwards is the result. In the joint between the two ranges of the carpus lateral movement can only take place in conjunction with the same movement in the radio-carpal joint. In such movements the scaphoid, semilunar and cuneiform move one on another, so that in inward flexion their transverse curve is flattened, and in outward flexion it is increased, and in this way their under surfaces are adapted to the irregular transverse curve formed by the upper surfaces of the lower range. The flattening of the upper range is effected less by an upward than by a backward movement of the scaphoid and cuneiform on the sides of the semilunar; and the same movement takes place to a greater extent in over-extension of the wrist, when the upper range rests on the less convex dorsal part of the surfaces of the os magnum and unciform. The amount of movement allowed between the carpals of the second range and between the bases of the second and third metacarpals is not sufficient to produce obvious changes of form; but when pressure is brought down on the over-extended hand the transverse arches of the second carpal range and metacarpal bases are flattened sufficiently to make tense the palmar and interosseous ligaments, which spring back into their previous condition on removal of pressure, and by this means great elasticity is secured.

The opposed surfaces of the trapezium and first metacarpal, being saddle-shaped, allow movement of the thumb in every direction. The opposed surfaces, however, do not accurately fit but have their convexities narrower than the opposed concavities. When the thumb is thrown back, only the posterior parts of the opposed surfaces are in contact. When it is bent inwards and forwards over the palm there is a slighter gap posteriorly; and in abduction with slight flexion the inner half of the metacarpal surface is in accurate contact with the outer half of the trapezial surface.

The metacarpo-phalangeal and interphalangeal articulations are hinge-joints; but the metacarpo-phalangeal articulations, with the exception of the

first, allow lateral movement in the extended position so as to separate the fingers and bring them together. The lateral movement is allowed by the lateral ligaments being attached far back on the sides of the metacarpals. In consequence of this, while both external and internal ligament are tight in flexion, they are so slack in extension as to allow the surfaces to be separated for about a tenth of an inch. When the hand is open the fingers are in one flat plane, and spaces may be seen between them when held up to the light; but when the hand is cupped the joints of one finger fit against the phalanges of the next, making the cup water-tight, and the fourth and fifth metacarpals, whose bases move more freely on the carpus than do the second and third, are bent forwards so that the bases of the fingers lie in the circumference of a circle and their tips are crowded together. In clenching the fist, the fourth and fifth metacarpals are still further pulled forwards, so as at once to dig the tips of the inner fingers more firmly into the palm and make the knuckle of the third finger more prominent.

THE LOWER LIMB.

The lower or pelvic limb, called also the inferior extremity, is divisible into hip, thigh, leg and foot. To the hips belong the innominate bones, which, unlike the shoulder-girdle, are firmly articulated with the vertebral column, joining together with the sacrum and coccyx in the construction of the pelvis. The thigh has but one bone, the femur; the knee-joint is protected in front by a large sesamoid bone, the patella; in the leg are the tibia and fibula; and in the foot the bones are arranged in groups—the tarsus, metatarsus and phalanges.

Fig. 161.—Right Innominate Bone about the Twelfth Year, from the deep side. The three elements—ilium, ischium, and pubic bone—meet opposite the acetabulum, with an epiphysis between them.

The Innominate Bone and Pelvis.

The *innominate*, *pelvic* or *hip-bone* consists of three parts—the *ilium*, *ischium* and *os pubis*—distinct in early life, and all taking part in the formation of the *acetabulum*, the articular cavity into which the head of the femur fits. The ilium expands upwards from the acetabulum, articulates with the sacrum and forms the lateral boundary of the expanded space called the *false pelvis*, at the same time that it enters into the formation of the smaller space called the *true pelvis*, the brim or inlet of which is formed above and behind by the base of the sacrum, and forwards from the sacrum to the acetabulum by the ilium, and from the acetabulum to the middle line in front by the os pubis. The ischium lies posterior to the os pubis and articulates with both it and the ilium at the acetabulum. Proceeding from the

acetabulum, the ischium and os pubis inclose between them the large *thyroid* or *obturator* foramen, filled up in the fresh state by the obturator membrane, except at its upper part, where the obturator vessels and nerve emerge. Thus, the whole innominate bone consists of two expansions meeting at the acetabulum, lying in planes at a considerable angle one to the other; the upper expansion formed by the ilium, and the lower perforated, and formed by the ischium and os pubis.

The *position* which the innominate bone occupies in the erect posture is similar to what is obtained by allowing it to hang from the middle of the crest of the ilium. The parts named anterior superior spines of

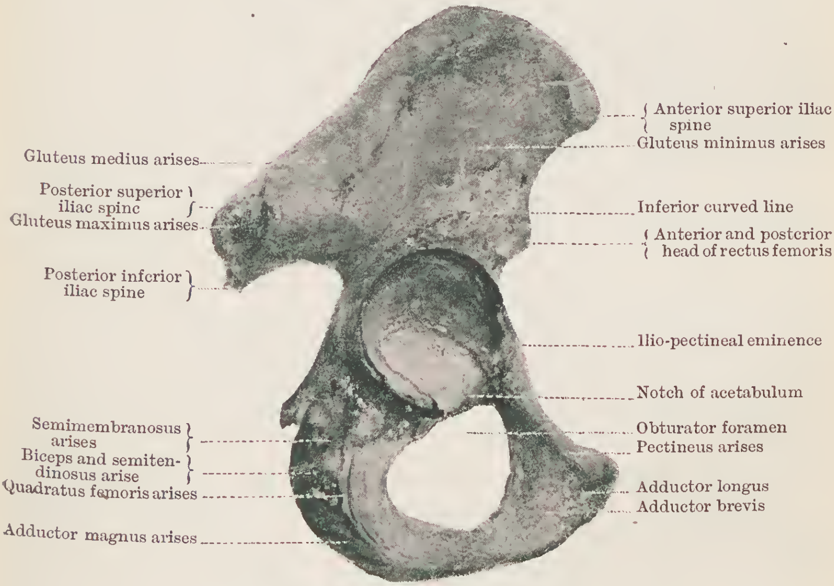


FIG. 162.—RIGHT PELVIC BONE, outer side.

the iliac bones and spines of the pubic bones lie nearly in one vertical transverse plane; and the tuberosity of the ischium descends little lower than the symphysis pubis.[1]

The ilium expands upwards from the acetabulum as a flat blade surmounted by a convex border, the *crest*, which rises highest in the middle of its course, and, looked at from above, is curved like the letter S, forming

[1] Formerly many erroneous ideas prevailed on this subject. In the great work of Vesalius, *De Fabrica Humani Corporis*, the celebrated figures attributed variously to Titian and to J. Calcar place the pelvis in such a position that the sacrum passes downwards in a direction from base to apex, like the keystone of an arch of masonwork; and this error remained prevalent in the first half of the present century, even although in the *Anatomia* of Bartholinus, and more distinctly in Cheselden's plates, the representation is correct. I am obliged to my former student, Dr. William Jack, for directing my attention to the remarkable fact that Leonardo da Vinci has figured the position accurately, da Vinci having by his private researches kept himself right, where Vesalius and either Titian or Titian's distinguished pupil went astray.

a concave boundary to the false pelvis, and bending in the opposite direction behind. The crest is thick in the fore and back parts of its course, and thinner between. The anterior thick part presents two lips separated by a ridge, the outer lip giving attachment to the fibres of the external oblique muscle of the abdomen, and the inner to the internal oblique and the transversalis: the middle thin part gives attachment externally to the hinder portions of the oblique muscles and to fibres of the latissimus dorsi, and internally to the quadratus lumborum, while the posterior aponeurosis of the transversalis muscle lies between; and the thick back part gives attachment to the lumbar fascia and deep muscles of the back, showing also on the inner side of the fore part of the surface devoted to them the mark of attachment of the ilio-lumbar ligament. The anterior projecting extremity of the crest is called the *anterior superior spine*, and affords attachment in front to the sartorius muscle, outside to the tensor fasciae femoris, and internally to Poupart's ligament. Separated from it by a short concave edge, the *anterior inferior spine* projects forwards, and gives origin to the anterior head of the rectus femoris muscle and to the ilio-femoral ligament; and below this the border of the ilium forms along with the pubic bone a convexity in front of the acetabulum, the *ilio-pectineal eminence.* The posterior extremity of the crest is called the *posterior superior spine*, and is separated by a short and sharp concave margin from the *posterior inferior spine*, which supports internally the posterior extremity of the articular surface for the sacrum. Beneath this, the border is hollowed out, forming the greater part of the *great sciatic notch.*

The *dorsum ilii*, or outer surface, presents areae for the attachment of the gluteal muscles; namely, posteriorly, for the gluteus maximus, a rough surface, extending down to the great sciatic notch; in front of this, for the gluteus medius, a space broad behind and narrow in front, bounded below by a linear mark, the *superior curved line*, extending from outside and behind the anterior superior spine back to the great sciatic notch; and below this line a space for the gluteus minimus, broader in front than behind, and extending down to the *inferior curved line*, which curves back to the great sciatic notch from the anterior inferior spine. The interval between the inferior curved line and the acetabulum is covered by the gluteus minimus, and over the upper edge of the acetabulum there is a considerable roughness from which the reflected head of the rectus femoris muscle arises.

The internal surface of the ilium presents an expanded, smooth and slightly concave surface, the *iliac fossa*, giving origin to the iliacus muscle and bounding the false pelvis. Below this it also enters into the construction of the true pelvis, by a part separated from the iliac fossa by a smooth border which is continued forwards on the os pubis to its spine, and is named in its entirety the *ilio-pectineal line.* Behind the iliac fossa a rougher area extends backwards, on which may be distinguished, in-

feriorly, the *auricular surface* for articulation with the sacrum; superiorly, a rough elevated part giving origin to the dorsal sacro-iliac ligament; and between the two a sinuous depression free from ligament, and ending behind between the two posterior spines. The auricular surface is somewhat crumpled, like the corresponding surface of the sacrum, broader in front than behind, with a retreating angle looking upwards and backwards, and its lower margin horizontal.

The ischium is most massive where it forms the back part of the acetabulum. On its posterior border, behind the acetabulum, there projects backwards and inwards a compressed process, *the spine*, which at its extremity is continued into the small sacro-sciatic ligaments, and on its deep and superficial surfaces respectively gives attachment to the coccygeus and gemellus superior muscles, without being marked by them. Beneath the spine is the *small sciatic notch*, with a smoothly grooved surface, over which the tendon of the obturator internus muscle turns, and bounded inferiorly by the *tuberosity*. The tuberosity projects downwards and backwards, and tapers forwards beneath into the *ramus*. The main surface of the tuberosity is divisible into a close-grained quadrate upper part for the hamstring muscles, and a rougher lower part continued into the ramus and giving attachment to the adductor magnus muscle. The quadrate upper part is divided by a diagonal line into a lower and inner portion which gives attachment to the combined origin of the semitendinosus muscle and the long head of the biceps, and an upper and outer portion from which the semimembranosus tendon arises. Above this surface the gemellus inferior arises, and, from the rough external margin, the quadratus femoris; while to its inner margin the great sacro-sciatic ligament is attached.

The *ramus* of the ischium, narrow and slender, prolonged from the lower part of the tuberosity, stretches forwards to meet the inferior ramus of the os pubis and complete the obturator foramen. Its lower border, continuous with the surface of the tuberosity devoted to the adductor magnus, gives origin to the upper fibres of that muscle, while its upper border is continuous with the anterior border of the main body of the ischium, and like it enters into the formation of the thin edge of the obturator foramen. On its deep side it gives attachment to the obturator internus muscle, and on its superficial side to the obturator externus muscle, whose fibres, as they pass outwards, are gathered together and lie in the broad groove between the acetabulum and tuberosity.

The **os pubis** forms the fore part of the acetabulum and the anterior portion of the brim of the pelvis, and presents an elongated oval surface for articulation with its fellow of the opposite side by means of an imperfect joint called the *symphysis pubis*. It joins with the ischium, both externally and internally, so as to surround with it the obturator foramen; and in its whole extent its pelvic or deep aspect is smooth, as is also that of the ischium.

The part in front of the obturator foramen is called the *superior* (or *ascending*) *ramus*, while the broad part which lies beween the obturator foramen and the symphysis is the body, and the narrower portion from this to the ramus of the ischium is distinguished as the *inferior ramus*. The superior ramus presents toward the obturator foramen a surface obliquely grooved in a forward and inward direction for the passage of the obturator vessels and nerves, and on the brim of the pelvis exhibits the pubic part of the ilio-pectineal line, which limits a smooth surface looking forwards, whence the pectineus muscle takes origin. The ilio-pectineal line ends about three quarters of an inch or more from the symphysis, in a more or less prominent *spine* to which Poupart's

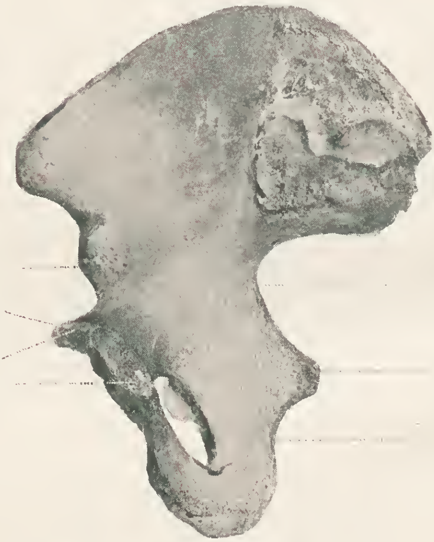


FIG. 163.—RIGHT PELVIC BONE, deep side.

ligament is attached; while sloping from spine to symphysis is a rough *crest* to which the rectus abdominis and its sheath are attached. The body of the pubis decreases in thickness from the superior to the inferior ramus, and from near the symphysis to the obturator foramen. Beneath the crest it gives attachment to the tendinous origin of the adductor longus, and by the greater part of its superficial surface to the adductor brevis muscle. Internal to these is a ridge for the adductor gracilis, fascia lata and dartos, and between the ridge and the symphysis a space for the inter-femoral ligament of the symphysis.

The *acetabulum* or *cotyloid cavity* is deeply cup-shaped, surrounded by a prominent margin, except at the fore part of its ischial portion, where the margin is absent and a *notch* is left looking downwards and slightly forwards. A non-articular depression continued in from the notch occupies the middle of the cavity, and the articular surface curves round this

depression, behind, above and in front of it; its posterior part formed by the ischium, its middle part, which is also the largest and looks downwards, formed by the ilium, and its anterior part, the smallest of the three, formed by the os pubis. The acetabulum looks forwards, outwards and downwards; and, therefore, in the erect posture, embraces the head of the femur behind, above and internally, while it leaves it exposed in front.

The **pelvis** has its inlet or *brim* extending from the promontory of the sacrum, round by the ilio-pectineal lines, to the upper border of the symphysis pubis, while its outlet exhibits three prominences, namely, the coccyx and the ischial tuberosities, the latter being united, in the recent state, to the coccyx by the great sacro-sciatic ligaments. Between the ischial tuberosities and the symphysis pubis is the *pubic or sub-pubic arch*, the margins of which give attachment to the corpora cavernosa, the triangular ligament and muscles of the perinaeum. The pelvic cavity being bounded behind by the sacrum and coccyx, and in front by the symphysis pubis, the *axis of the pelvis*, a line drawn so as to be everywhere equidistant between those boundaries, is considerably curved. As, however, the sacrum and coccyx do not lie in a circular curve, and as the sacrum is to a certain extent movable round the retreating angle of its auricular surface, and the coccyx movable on the sacrum, the best expression of the total curvature of the pelvis is to be found in the facts that the tuberosities of the ischia descend, in the erect posture, little below the symphysis pubis, and that the brim of the pelvis lies at an angle approaching 60 degrees to the horizontal plane.

The male and female pelvis present a number of differences not any of them to be found in every instance, but all of them present in well-

Fig. 164.—Pelvis of Male.

Fig. 165.—Pelvis of Female.

formed specimens. The diameters of the true pelvis are particularly important in the female. In the full-grown normal European female the average transverse, oblique and antero-posterior (or *conjugate*) diameters may be estimated respectively as $5\frac{1}{4}$, 5 and $4\frac{1}{2}$ inches at the brim, and each as about $4\frac{3}{4}$ inches at the outlet, the transverse diameter slightly narrowing from brim to outlet, while the conjugate increases below the

sacral promontory. In the male these diameters are smaller, and the ischial tuberosities less everted, and on both accounts the pelvis is deeper and the pubic arch narrower; also the obturator foramen has less approach to a triangular form. An additional sexual distinction in the pubic arch is occasioned by there being constantly in the adult female greater breadth between the lines of origin of the graciles muscles; but the growth of this breadth is the last part of the ossification of the innominate bone to be completed.

At different ages the pelvis has different shapes. In early childhood the iliac blades diverge at a wide angle one from the other and the pelvic outlet is of small proportions; but from about the time of appearance of the permanent incisor teeth the angle of *iliac divarication* as measured by the anterior borders of the blades diminishes from as much as 85 degrees till, when early adult life is reached, it may vary from 20 to 40 degrees, while, in later life it again increases notably, especially in heavy pelvises, doubtless in consequence of muscular traction. The conjugate and transverse diameters of the pelvic brim are about equal in young children; afterwards the conjugate grows more rapidly than the transverse till near puberty, and finally the adult proportions are approached by more rapid increase in width, apparently due to the transmission of the weight of the body through the dorsal sacro-iliac ligaments whose surfaces of attachment become much enlarged. In lower races of humanity these later changes are more or less completely absent, the pelvis remaining of a form termed by Turner *dolichopellic*, but expressed in connection with its mode of development as *unbroadened*.[1]

The Femur.

The **superior extremity** of the femur or thigh bone presents a rounded head and an elongated neck, separated from the shaft by an outer and an inner eminence, the great and the small trochanter, with an anterior rough line and a posterior ridge uniting them. The *head* has a spherically curved surface forming more than half a sphere, and encroaching on the neck considerably further above than below. Below and behind the position of a line prolonged up the centre of the neck, its surface is interrupted by a depression, which gives attachment to the round ligament of the hip-joint. The *neck* is directed upwards and inwards from the shaft at an angle varying from 110 to 140 degrees, more obtuse in the male than the female, and in the young than the old. If the posterior extremities of the condyles at the lower end of the bone be placed in a transverse plane the neck is inclined distinctly forwards. It is thicker from above downwards than from before backwards, and has three sides separated by a superior, an inferior, and a less prominent posterior border. The *great trochanter* projects upwards in a line with the outer part of the shaft. Looked at

[1] Cleland, *Memoirs and Memoranda in Anatomy*, Vol. i., p. 95.

from the outside it presents a square surface limited below by a line to which the vastus externus muscle extends, and crossed diagonally from

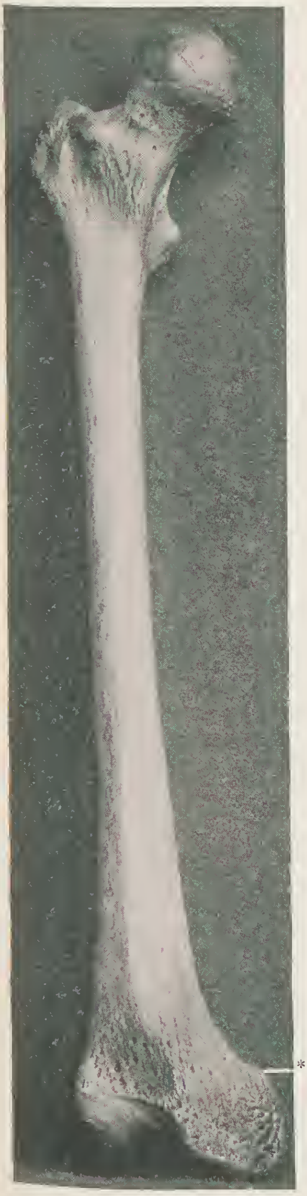


FIG. 166.—RIGHT FEMUR, front view.
* Spine of adductor magnus.

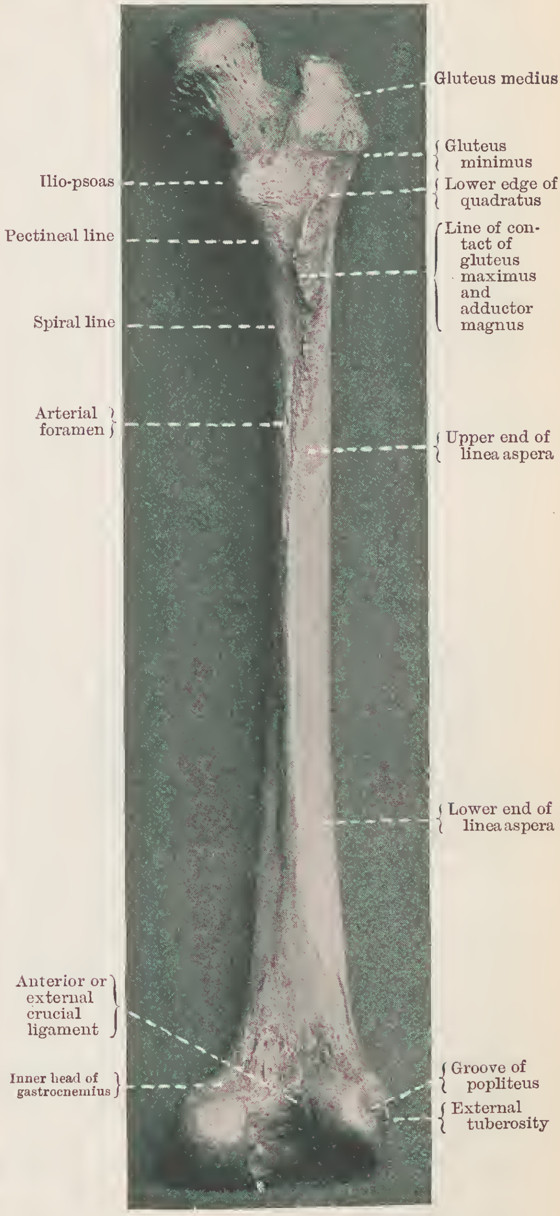


FIG. 167.—RIGHT FEMUR, hinder view.

above downwards and forwards by another indicating the inferior border of the insertion of the gluteus medius. Below this diagonal the surface

is smooth, while above it there is an uneven appearance where bursae intervene between tendinous bundles. Continuous with the diagonal line, there is a roughness in front of the base of the trochanter, indicating the insertion of the gluteus minimus. On the summit the tendon of the pyriformis muscle is inserted. Internal to the great trochanter is the *trochanteric* or *digital fossa*, bounded in front by the upper border of the neck, and below by the posterior border. Into this fossa is inserted the obturator externus muscle, and on the ridge in front of it is a flat impression where the obturator internus is inserted. The *small trochanter* is a spinelike projection inwards from the posterior and inner part of the top of the shaft, behind the lower border of the neck, and gives attachment to the ilio-psoas muscle. It is connected with the back of the great trochanter by means of a thick smooth bar looking upwards, the *posterior intertrochanteric ridge*; while, in front, a rough *line* called *anterior intertrochanteric* begins at the great trochanter by a tubercle at the upper and inner side of the insertion of the gluteus minimus, and extending downwards and inwards to the inner border of the shaft, passes thence upwards and backwards in front of the small trochanter. The roughness of this line is caused by the insertion of the strong anterior fibres of the capsule of the hip-joint; the tubercle being the attachment of the outer band of Bigelow's ligament, and the pointed projection downwards at its inner part that of the ilio-femoral band. The origin of the vastus externus reaches to the tubercle, and the combined crureus and vastus internus to the anterior intertrochanteric line, as far inwards as the downward projection; while below this, the limit of the vastus internus continues to be indicated by a much slighter mark, *the spiral line.*

The **shaft** is directed downwards, inwards, and backwards, in standing with the knees straight and the feet together. It has a continuous curve, with the convexity forwards, and in its lower third gradually increases in thickness. In the middle third it presents posteriorly a rough ridge, the *linea aspera*, continued upwards into a rough surface whose boundaries extend toward the two trochanters, and inferiorly prolonged into two *supracondylar lines* which extend to the sides of the back parts of the condyles, and inclose a smooth triangular surface looking into the popliteal space. The whole surface in front of the linea aspera and its prolongations is smooth and clothed by the vasti and crureus muscles, and thus the middle third of the shaft shows an anterior surface continued into an outer and an inner surface by rounded borders, and the outer and inner surfaces separated behind by a prominent ridge. But the linea aspera presents throughout two prominent lips, with an intervening line which represents a broader surface in lower animals. Into the linea aspera are attached from within outwards, between the vasti muscles, the adductor longus, part of the adductor magnus, and the greater part of the short head of the biceps. The inner supracondylar line gives insertion to lower fibres of the adductor magnus, and ends inferiorly

in a *spine* marking the insertion of a tendon in which the longest fibres of the muscle end; while the upper part of the outer line gives origin to the lower fibres of the short head of the biceps. The surface prolonged up from the linea aspera is divided by a prominent line into an inner and an outer portion. The inner portion is mainly devoted to the upper part of the adductor magnus muscle, internal to which are inserted the adductor brevis, pectineus and iliacus, while in front of the small trochanter the spiral line already mentioned comes down to the linea aspera. The outer portion is a rough surface for insertion of the gluteus maximus, and is usually rather depressed except at its upper end, a little below the base of the great trochanter, where it rises in a prominence and receives the pull of the large part of the muscle whose tendinous fibres are at first spread out in the fascia lata. Above this, and extending up a little on the back of the great trochanter, is the place of attachment of the quadratus femoris. About the middle of the linea aspera is placed the *arterial foramen* for the medullary vessels, which slopes upwards into the bone.

The **inferior extremity** presents a large articular surface divided by slight marks into three parts, namely, an anterior surface for the patella and two rolling surfaces or condyles which articulate with the tibia and extend backwards, separated by a deep *intercondylar fossa.* The *patellar surface* is grooved from above downwards, and the part of it outside the groove is transversely convex and broader than the part internal to the groove, and is considerably more prominent, throwing the patella inwards when the knee is straight. Both the condyles are convex from side to side, and helicoid in their longitudinal curve. The outer condyle is the shorter and broader, and has its outer border projecting but slightly further out than the patellar surface. The inner condyle lies in greater part parallel with the outer; but its outer border being almost directly behind the inner edge of the patellar surface, its inner border has in its fore part an outward curve. The separation of the outer condyle from the patellar surface is marked by a sharp line with a groove behind it commencing externally with a notch and directed inwards and slightly backwards to the intercondylar fossa; the limit of the inner condyle is marked

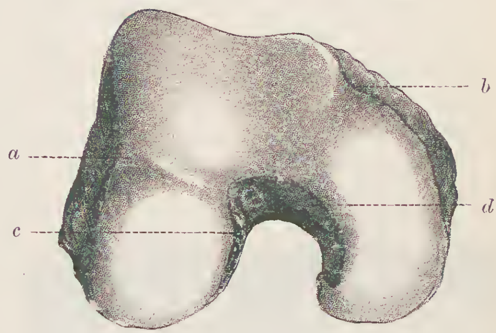
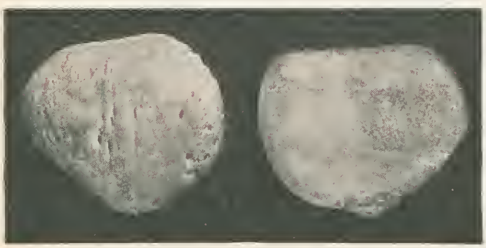


Fig. 168.—Inferior Extremity of Right Femur. *a*, *b*, The depressions in front of the outer and inner condyles, separating them from the patellar surface, and receiving the semilunar fibro-plates of the knee-joint in complete extension; *c*, *d*, the marks of attachment of the external or anterior, and the internal or posterior crucial ligaments. The shaded strip on the outer side of the internal condyle is the surface on which the inner facet of the patella rests in extreme flexion.

by a similar line and groove beginning internally further forwards and directed more backwards, but the groove disappears before reaching the fossa, and the line changing its direction cuts off a narrow *patellar strip* on the outside of the condyle from the tibial surface. In the erect posture the two condyles rest on the tibia in a horizontal plane while the shaft is oblique; but when the knee is bent, the inner condyle projects forwards in the same direction as the shaft and pushes the patella to the outside. The posterior extremities of the surfaces of the condyles turn upwards to the base of the triangular area of the shaft; and here the outer condyle becomes narrow and slightly curved inwards, and, when the shaft is held vertically, comes a little higher than the inner condyle. Above the back of the inner condyle a rough surface indicates where the inner head of the gastrocnemius muscle arises; a weaker mark similarly placed above the outer part of the back of the external condyle gives attachment to the plantaris, while a depression outside the extremity of this condyle is the place of origin of the outer head of the gastrocnemius. On the sides towards the back, about the centre of the helix described by the condyles, are the *external* and *internal tuberosities* which give attachment to the lateral ligaments of the knee-joint; and below and behind the external tuberosity is a deep groove, directed downwards and forwards, the *popliteal groove*, lodging the popliteus tendon in the flexed position of the knee, and at its lower and fore part giving attachment to it. A very slight but constant depression in the lower border of the groove marks the position of the tendon when the knee is extended (Mackay). Within the intercondylar fossa there are two special roughnesses: one for the anterior or external crucial ligament is placed well back on its outer wall, and the other for the internal or posterior crucial ligament is at the fore part of the fossa.



A B

Fig. 169.—Patella. *A*, Superficial view. *B*, deep view, showing the articular surface with its vertical ridge dividing superior, middle and inferior facets, and the seventh facet on the inner edge.

The Patella.

The patella (*rotula*) or knee-pan is of the nature of a sesamoid bone, developed in the insertion of the quadriceps extensor femoris. It is broad above, pointed below, flattened superficially, thick at its straight superior margin where the rectus femoris and crureus are inserted. Its deep surface is articular, except at the lower part, which is rough and, together with the edges of the pointed projection below, gives attachment to the ligamentum patellae. The articular surface is divided by a vertical elevation into a broader external portion transversely concave, and a narrower

internal portion transversely convex; and both in macerated specimens and in those covered with cartilage two slight transverse elevated lines subdivide each of these portions into a broad middle facet and narrower facets above and below, while, close to the inner margin, a vertically elongated seventh facet is seen, which comes in contact with the patellar strip of the inner condyle of the femur when the knee-joint is bent to its utmost in sinking down on the hams and balls of the toes.

THE BONES OF THE LEG.

As in the forearm, so also in the leg there are two bones, the tibia and the fibula. The fibula is, however, much more slender than the tibia in its whole length. In mammals it does not enter into the knee-joint, and it forms little or no part of the pillar of support through which the weight of the body is conducted to the foot. At the ankle only one bone of the foot, the astragalus, articulates with the leg, and it lies underneath the tibia; while the joint is guarded at the sides by two projections called *malleoli*, the inner formed by a process of the tibia, and the outer by the lower end of the fibula.

The Tibia.

At its **upper extremity** or *head*, the tibia or shin bone is expanded, especially transversely, and supports an *outer* and an *inner condylar* surface placed side by side with a narrow interval between. Both of these are rather concave in the middle where the condyles of the femur principally rest, and toward the circumference of the bone they are bevelled where they come in contact with the semilunar fibro-plates, and they turn abruptly upwards with a slight twist in the middle of their contiguous borders, forming the double summit of an elevation termed the *spine*. The inner articular surface is considerably longer from before backwards than the outer. The rough interval between the two is elevated where it takes part in forming the spine. Behind this, it sinks into a depression, the *popliteal notch*, from which springs the posterior or internal crucial ligament; and in front it is wider, giving origin by its inner two thirds to the anterior or external crucial ligament, and in its outer third presenting a smoother groove to lodge the external semilunar fibro-plate when the knee is extended. At the sides, the head projects beyond the shaft, forming the *outer* and *inner tuberosity*. The inner tuberosity presents a horizontal groove in which lies one of the insertions of the semimembranosus muscle. Towards the back of the external tuberosity there is a small articular surface for the fibula, looking outwards, downwards and backwards; and in front of this a minute area, giving attachment to the tip of the extensor longus digitorum, intervenes between the fibular surface and a line which curves forwards limiting the origin of the tibialis anticus from the shaft.

FIG. 170.

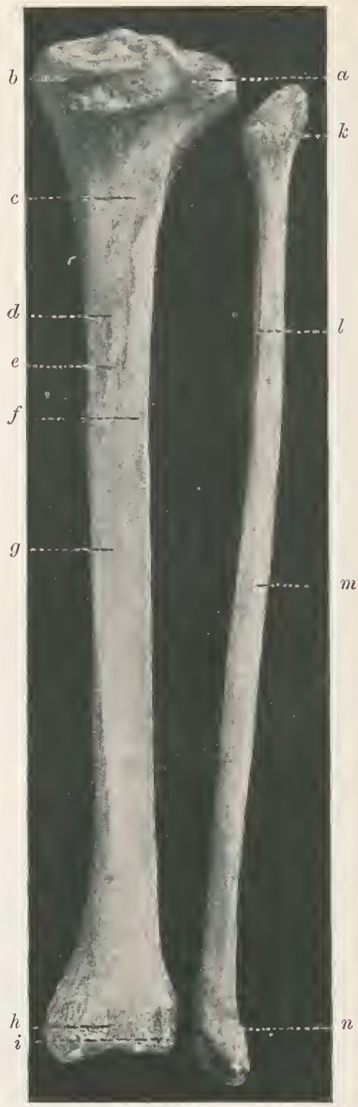


FIG. 171.

FIG. 170.—RIGHT TIBIA AND FIBULA from the front. *a*, Groove of tendon of semimembranosus; *b*, *b'*, anterior tuberosity of tibia, *b*, surface for bursa, *b'*, insertion of ligamentum patellae; *c*, attachment of internal lateral ligament; *d*, lower end of insertion of sartorius, gracilis, and semitendinosus; *e*, origin of tibialis anticus; *f*, mark of insertion of fibres continuous with tensor fasciae femoris, and below it the tibial origin of extensor longus digitorum; *g*, subcutaneous spot on head of fibula; *h*, *i*, origins of peroneus longus and brevis; *k*, origin of extensor longus digitorum; *l*, peroneus tertius; *m*, subcutaneous area.

FIG. 171.—RIGHT TIBIA AND FIBULA from behind. *a*, Popliteal notch; *b*, groove of tendon of semimembranosus; *c*, muscular attachment of popliteus; *d*, oblique line of origin of soleus; *e*, arterial foramen; *f*, surface for tibialis posticus; *g*, surface for flexor longus digitorum; *h*, crosses the groove for tendon of tibialis posticus; *i*, crosses the groove for tendon of flexor longus hallucis; *k*, fibular origin of soleus; *l*, fibular origin of tibialis posticus; *m*, origin of flexor longus hallucis; *n*, groove behind external malleolus for tendons of peroneus longus and brevis.

Also, it is worthy of note that in front of the external tuberosity, between the tip of the area for the tibialis anticus and the inner condylar surface, there is a constant fine-grained impression connected with the insertion of the band of fascia lata continued down from the tensor fasciae femoris, and running back from this a horizontal groove close to the condylar surface. In front, at a lower level than the outer and inner tuberosity, there is a thick projection, the *tubercle* or *anterior tuberosity*, smooth in its upper part where a bursa is placed, and rough below, where it gives attachment to the ligamentum patellae.

The **shaft** is three-sided and tapering in the greater part of its length, but toward the lower end it loses the three-sided form and slightly increases in size. An *inner border*, rounded above and below and more distinct in the middle, separates the internal from the posterior surface; the sharp *anterior border* or *crest* separating the external from the internal surface descends from the outer side of the tubercle, and is smoothed away in the lower fourth of the shaft; while the *outer border*, giving attachment to the interosseous membrane between the tibia and fibula and separating the external from the posterior surface, passes down from the articular surface for the head of the fibula to a rough area looking outwards, on which that bone rests at the lower end. Thus, the *external surface*, looking forwards and outwards in its upper three-fourths, is turned so as to look forwards below: in its upper two-thirds it is transversely concave, and gives origin to the tibialis anticus. The *internal surface* is subcutaneous; at its upper part it presents a rough area outside the tubercle, where the tendons of the sartorius, gracilis, and semitendinosus muscles are inserted one over another, and behind this a more distinct and elongated roughness where the internal lateral ligament of the knee-joint is inserted. The *posterior surface* is crossed above by a strongly marked oblique line running downwards and inwards from the articular surface for the fibula and marking the attachment of the soleus muscle. The triangular area above this line gives origin to the popliteus muscle, and a smooth longitudinal ridge descending a short distance below it separates an outer area giving origin to the tibialis posticus from a larger area to which the extensor longus digitorum is attached. On the outer side of this line is situated the *arterial foramen* for the medullary vessels, sloping downwards into the bone, and remarkable as the largest foramen of the sort in the body.

The **lower extremity** is somewhat broadened out and has projecting downwards on its inner side a stout process, the *internal malleolus*, while externally it presents a surface concave from before backwards, against which lies the lower end of the shaft of the fibula. The articular surface for the astragalus has its principal part directed downwards, quadrilateral in shape and broader in front than behind, concave from before backwards, slightly bevelled at the outer side, and with the posterior edge projecting downwards. On the inner side a continuation of the same articular

surface is turned down on the internal malleolus, deeper in front than behind, and in contact with the inner surface of the astragalus. Posteriorly two grooves are seen; one, behind the internal malleolus, is deep and has lying on it the tendon of the tibialis posticus, with that of the flexor longus digitorum on its surface; the other, slight, sometimes absent, placed at some distance outwards, marks the position of the tendon of the flexor longus hallucis.

The transverse diameter of the lower end of the tibia does not lie in the same plane as that of the head. If the heads of the two tibiae be placed with their backs in one transverse plane, the lower ends will be so directed outwards as to leave a right angle between the inner sides of the feet; but if the anterior edges of the surfaces for the thigh bones be placed in one straight line the feet will be parallel, and the articular surfaces of the internal malleoli will look directly outwards. In the erect posture the tibia, like the femur, is more advanced at its upper than at its lower end.

The Fibula.

The fibula or *peroneal* bone is arched more or less backwards, and at its upper end lies behind as well as outside the tibia, while below it is more directly external to it. Thus, an amputating knife, if passed behind the tibia from inside the leg, is liable to be locked in front of the fibula.

The **head** presents an oval surface looking upwards, forwards and inwards for articulation with the tibia, and superficially is subcutaneous. It gives attachment by prominences in front and behind to the ligaments uniting it to the tibia, and is surmounted towards the back by a *styloid process* to which the short band of the external lateral ligament of the knee-joint is attached; while the long band and the biceps flexor cruris muscle are inserted further forwards.

The **inferior extremity,** whose projection outwards is the *external malleolus,* descends further than the internal malleolus formed by the tibia, but is less prominent. It presents three surfaces. One of these, subcutaneous, looks outwards and forwards, is broadest opposite the lower margin of the tibia, and is bounded posteriorly by a vertical border, and anteriorly by one which curves downwards and backwards to meet it. A second surface looks backwards and presents a groove in which the tendon of the peroneus brevis descends, with the tendon of the peroneus longus muscle over it. The remaining surface looks inwards, and is divided into three parts, namely, a triangular articular facet convex from above downwards; a depressed and uneven part further back, giving attachment to ligaments; and an area above, looking toward the concave outer surface of the tibia, but rather too flat to fit accurately into it, limited in front and behind by two diverging rough lines, of which the hinder is the better marked.

The **shaft** is altogether clothed with muscles, except for a short distance above the external malleolus, whose subcutaneous surface is continued upwards a short distance and comes to a point, from which the sharp *anterior border* extends up to the head, giving attachment to the aponeurosis of the limb. Outside this border is the *external surface* continuously grooved from the head downwards, giving origin in its upper two-thirds to the peroneus longus and brevis muscles, and inferiorly turning backwards behind the malleolus. The *outer border*, behind the peroneal muscles, likewise gives attachment to the aponeurosis of the limb. It separates the external from the *posterior surface*, which is convex in its upper three-fourths, and twists inwards inferiorly to end at the rough surface for the inferior interosseous ligament. The posterior surface is roughened by the fibular origin of the soleus muscle for two or three inches downwards from the head, and gives attachment in the greater part of the rest of its extent to the flexor longus hallucis. It is separated by a sharp *internal border* from the *internal surface*, which is sometimes described as two, because it is diagonally crossed from above downwards and backwards by a ridge giving attachment to the interosseous membrane, the partition separating the anterior from the posterior muscles of the leg. The portion in front of this ridge gives attachment to the extensor longus digitorum and peroneus tertius muscles; and the portion behind affords origin to the outer part of the tibialis posticus; while a few fibres of the extensor hallucis arise from the lower part of the ridge itself.

THE BONES OF THE FOOT.

The Tarsus.

The tarsus consists of seven bones, of which the two largest, the astragalus and the calcaneum, are placed behind, the astragalus resting on the calcaneum. The astragalus is inclined forwards and inwards, and carries in front of it the scaphoid, which supports the three cuneiform bones, while these in turn carry in front of them the metatarsals of the three inner toes. The calcaneum is inclined forwards and outwards, and supports the cuboid bone, which carries in front of it the two outer metatarsal bones. Thus the cuboid and the three cuneiforms together form an anterior row articulating with the five metatarsals.

The **astragalus** or **talus** articulates with the tibia and fibula by means of an articular surface which, fitting in between the malleoli, extends over its *body*. Continued forwards in front of the inner two-thirds of the body is the *neck*, supporting an articular *head* which enters into the astragalo-calcaneo-scaphoid articulation and has its surface prolonged backwards inferiorly as far as a deep groove directed obliquely underneath the part covered by the superior articular surface, and giving attachment to the interosseous astragalo-calcaneal ligament. This groove has its outer end in

front of the body, while its inner end is close to the posterior extremity of the bone, and the whole of the space behind the groove is occupied

Fig. 172.—Right Foot, Dorsal View.

Fig. 173.—Right Foot, Plantar View.

by an articular surface for the posterior astragalo-calcaneal articulation, a joint into which the calcaneum and astragalus are the only bones which enter.

The *superior articular surface*, taking part in the ankle-joint, is divided by prominent ridges into a central, an inner and an outer portion. The central portion looking upwards is convex from behind forwards, and slightly grooved longitudinally; its inner border is straight and nearly parallel with the inner side of the foot; its outer border is curved forwards and outwards so as to give greater breadth in front than behind, and is on the whole more prominent, but is flattened out behind to form an angular facet, which fits against a ligament and synovial pad between tibia and fibula when the foot is extended. The portion of the superior articular surface which looks inwards is a sickle-shaped strip, broadest in front and

narrowing to a point behind, and articulating with the internal malleolus. The portion looking outwards for articulation with the fibula is much larger, nearly quadrant-shaped, with the centre of the quadrant everted and pointing downwards and forwards.

The *surface for the posterior astragalo-calcaneal articulation*, behind the groove for the interosseous ligament, has its longer diameter concave and directed forwards and outwards from the hinder extremity of the bone, to end in front external to the neck, while its shorter diameter, at right angles to the longer, is flat. The *articular surface of the head* is clothed with a continuous sheet of articular cartilage, but presents as many as four facets. The largest of these, occupying more than half of the entire surface, looks forwards and fits into the concavity of the scaphoid bone. Beneath this, and separated from it by a distinct prominent line, there is placed externally a small facet which articulates with a surface on the inner third of the foremost part of the calcaneum, and internally a larger facet which lies in contact with the inferior calcaneo-scaphoid ligament, while, behind this, between it and the groove for the interosseous ligament, there is another facet for articulation with the sustentaculum tali of the calcaneum. The *posterior extremity* of the astragalus is non-articular and marked by a groove directed downwards and inwards, in which lies the tendon of the flexor longus hallucis muscle. At the outer margin of this groove there is a special prominence, the *posterior tubercle*, giving attachment to the posterior band of the external lateral ligament of the ankle-joint, and occasionally presenting a separate ossicle (*os trigonum*).

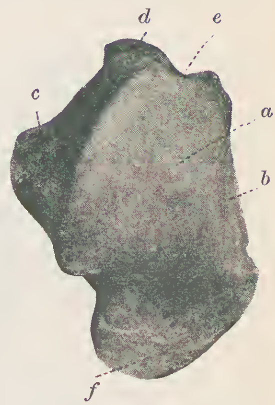


FIG. 174.—RIGHT ASTRAGALUS from above. *a*, *b*, *c*, Central, internal and fibular divisions of superior articular surface; *d*, angular facet which fits in between tibia and fibula in extension of the ankle-joint; *e*, groove for flexor longus hallucis; *f*, surface of head for articulation with the scaphoid.

The **calcaneum** or **os calcis** is an elongated block directed forwards, outwards and upwards, supporting the astragalus, and articulating in front with the cuboid bone.

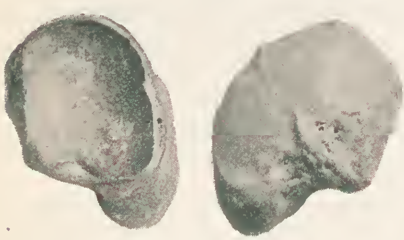
The *surface for the cuboid* is deepest externally, and in its internal half is deeply concave from above downwards, having an overhanging upper margin. The *surfaces for the astragalus* are separated by a rough groove for the interosseous astragalo-calcaneal ligament. The *anterior* of these surfaces articulates with the head of the astragalus and consists of two parts, one situated towards the inner side of the foremost part of the upper aspect, the other on a ledge projecting inwards further back, called *sustentaculum tali*; and these two portions, always forming distinct facets, are sometimes completely separate, and always move on separate areae of the astragalus. The *posterior* of the two surfaces for the astragalus articulates with the body of that bone, and is convex from behind forwards

and outwards. Placed in front of it, in continuity with the groove for the interosseous ligament, and external to the surface for the head of the astragalus, is a rough depression which gives attachment to the extensor brevis digitorum and to the loop of the anterior annular ligament, and forms the floor of a recess on the dorsum of the foot, outside the head of the astragalus.

A *B*

Fig. 175.—Right Calcaneum and Astragalus. *A*, Calcaneum from above. *B*, Astragalus from below. *a*, *a'*, Corresponding articular surfaces of posterior calcaneo-astragalar articulation; *b*, *b'*, corresponding surfaces of calcaneo-astragalo-scaphoid articulation; *b*, is situated on the sustentaculum tali; *c*, on the body of the calcaneum is often united with the sustentacular surface, and overhangs the surface for the cuboid; *e*, surface of the head of the astragalus for the scaphoid; and between *b'* and *e*, the surface which presses on the inferior calcaneo-scaphoid ligament. ×, Marks where the tendon of the flexor longus hallucis passes under the sustentaculum; ×', where it leaves the groove on the astragalus.

Behind the surfaces for articulation with the astragalus, a stout *neck* projects backwards and ends in the *tuberosity*, which is traversed by the rough mark of the insertion of the tendo-Achillis and is smooth and close-grained above for a bursa, while below it is subcutaneous. The subcutaneous part is continued round upon the under or plantar surface, and ends there in an *external* and *internal tubercle*, the internal the larger, to the fore part of which are attached the plantar aponeurosis and the superficial plantar muscles. The rest of the plantar surface is occupied principally by the long plantar ligament, and has a depressed rim in front for Haversian glands of the calcaneo-cuboid joint. Internally, a broad channel between the tuberosity and the sustentaculum tali leads from the back of the leg to the sole of the foot; and beneath the sustentaculum tali there is a groove for the flexor longus hallucis, continuous with that on the back of the astragalus. Externally, the calcaneum is subcutaneous, but crossed by the tendons of the peroneus longus and brevis, in connection with whose sheaths there are in some instances marks toward the fore part, the most frequent of which is a ridge or spine between them.



A *B*

Fig. 176.—Left Scaphoid. *A*, From behind. *B*, From the front.

The **scaphoid** or **navicular bone** is short from behind forwards, and has its longest diameter directed inwards and downwards. It presents a large concave articular surface behind for the head of the astragalus, and in front has a convex articular surface divided by lines into three facets for the three cuneiform bones, the middle facet shaped and placed like the keystone

of an arch. On the inner side, a *tuberosity* projects downwards which receives the main insertion of the tibialis posticus tendon. On the outer side there is sometimes a small facet for articulation with the cuboid bone.

The **internal cuneiform bone** is, as the name implies, wedge-shaped; the base of the wedge being directed downwards, forming a thick tuberosity placed in front of the tuberosity of the scaphoid, and curved somewhat into the sole, below the sharp apices of the middle and outer cuneiform bones. The outer surface, in its hinder two-thirds, lies inside the middle cuneiform, with which it articulates above and behind by means of an L-shaped surface, while further forwards it fits against the second metatarsal and articulates with it by a facet at the end of the L-shaped surface.

Fig. 177.—The Three Cuneiforms of Left Side. *A*, From the front and outer side. *B*, From the hinder and inner aspect.

The upper margin is sharp and directed upwards and outwards, as well as forwards, where in contact with the middle cuneiform; but in front of this is prolonged straight forwards and becomes more rounded. The posterior surface, articulating with the scaphoid, is concave and much shorter than the flat anterior surface for articulation with the first metatarsal. On the inner side there is an oblique depression, leading to a distinct mark at the lower and fore part, where the tendon of the tibialis anticus is mainly inserted.

The **middle cuneiform** bone is the smallest of the three cuneiforms, neither reaching so far forwards nor so far down as the others. Its dorsal surface is quadrate, little longer than broad. The posterior surface, articulating with the scaphoid, is slightly concave, and broader than the flat anterior surface for articulation with the second metatarsal. Internally it has an L-shaped surface, corresponding with that on the internal cuneiform, while externally there is a narrow articular surface along the posterior edge to articulate with the external cuneiform.

The **external cuneiform** projects forwards beyond the middle cuneiform, and is much longer than broad. Its articular surface for the scaphoid looks backwards and inwards, and is smaller than the anterior, which articulates with the third metatarsal bone. The inner side has an articular part in front of the posterior margin to articulate with the middle cuneiform, and a narrower articular facet at its anterior margin for the second metatarsal, while it is rough in the intermediate extent. The outer side looks towards the cuboid, and in its posterior part articulates broadly with it.

The **cuboid** is longest on its inner side, which is in large part rough, but articulates in the middle of its extent with the external cuneiform by means of a broad articular surface descending from the upper margin, and has sometimes a small articular facet further back for the scaphoid. Posteriorly, it articulates by a saddle-shaped surface with the calcaneum, and has a *conical process* projecting back from its lower and outer angle. Anteriorly, it presents an articular surface divided into two facets corresponding with the bases of the fourth and fifth metatarsal bones. Externally, it is short and reduced in height, and is grooved for the tendon of the peroneus longus. Inferiorly, this groove is continued inwards across the fore part, and in front of a prominent thick ridge which gives attachment to the long plantar ligament and the sheath of the tendon of the peroneus longus.

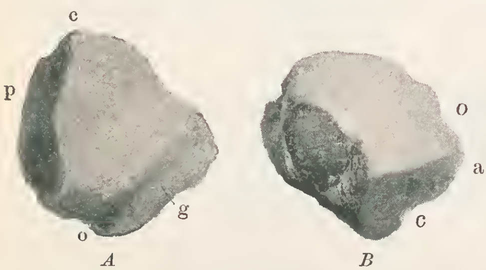


Fig. 178.—Left Cuboid. *A*, Plantar view. *B*, Dorsal view. *p*, Posterior surface; *a*, anterior surface; *o*, outer surface; *c*, conical process; *g*, groove for peroneus longus.

The Metatarsus.

The **first metatarsal bone**, that which belongs to the great toe, is shorter but much more massive than any of the four others. The *base* extends the whole height of the inner side of the transverse arch which is formed by the bases of the five together; it articulates with the internal cuneiform bone by a vertically elongated surface indented on its outer side, and presents a tuberosity below, which continues forwards the thick ridge formed by those of the scaphoid and internal cuneiform. This *tuberosity* presents on its inner side a smooth impression, completing with that on the internal cuneiform the mark of insertion of the tendon of the tibialis anticus muscle, and on its outer side a larger and rougher impression where the tendon of the peroneus longus is inserted. The large rounded *head* is in height about equal to its breadth; on its lower part it presents two grooves for two large sesamoid bones

situated in the tendons of the flexor brevis hallucis; a prominent ridge lies between the grooves, and another less prominent ridge bounds the inner groove internally.

The **four outer metatarsal bones** differ from metacarpal bones in tapering from base to head, and on the dorsal aspects presenting subcataneous surfaces broad at the bases and narrowing on the shafts, being continued in the second, third and fourth into a ridge between the origins of the dorsal interosseous muscles. The second metatarsal bone is longer and the fifth shorter than the third and fourth, and, in all, the shafts have an appearance of obliquity inwards, which is least marked in the second, and most distinct in the fourth and fifth. The heads have elongated articular surfaces, convex both longitudinally and from side to side, prolonged and bifid below; on each side, behind the head there is a lateral projection near the dorsum, where the lateral ligament is attached.

The **second metatarsal** articulates, at its base, behind with the middle cuneiform bone; internally, by only a small facet with the internal cuneiform, and sometimes by a less distinct facet with the first metatarsal: and, externally, it is characterized by a surface, or more generally two, an upper and a lower, divided into two facets, one in front of the other, to articulate with the external cuneiform and the third metatarsal.

The **third** articulates behind with the external cuneiform bone, internally with the second metatarsal, and externally with the fourth.

The **fourth** articulates behind with the cuboid by a surface narrower than the corresponding surface of any other metatarsal bone, and externally and internally by large facets with its neighbours; while, behind that for the third metatarsal bone, it has usually a small additional facet opposed to the outer edge of the external cuneiform bone.

The **fifth** articulates behind with the cuboid bone, and internally with the fourth metatarsal, and is easily distinguished by a large tuberosity projecting outwards and backwards at its base, to give attachment to the tendon of the peroneus brevis muscle.

The Phalanges.

The phalanges of the foot correspond in number with those of the hand, and the distinguishing characteristics of their extremities are similar. The phalanges of the great toe are larger than those of the thumb. In the four outer toes all the phalanges are smaller than the corresponding bones of the fingers; the phalanges of the first row are nearly circular at the large base and at the narrowest part of the constricted shaft; those of the second and third rows are remarkably short, only the second phalanx of the second toe being, as a rule, as much as twice as long as it is broad. In the fifth toe the dwindling is so extreme that the last two phalanges are frequently united by bony union.

ARTICULATIONS OF THE LOWER LIMBS.

The Pelvis.

The ilio-lumbar and **lumbo-sacral ligaments** are two strong bands which extend from the transverse process of the last lumbar vertebra, the one downwards to the sacrum, the other outwards to expand on the inner side of the crest of the ilium.

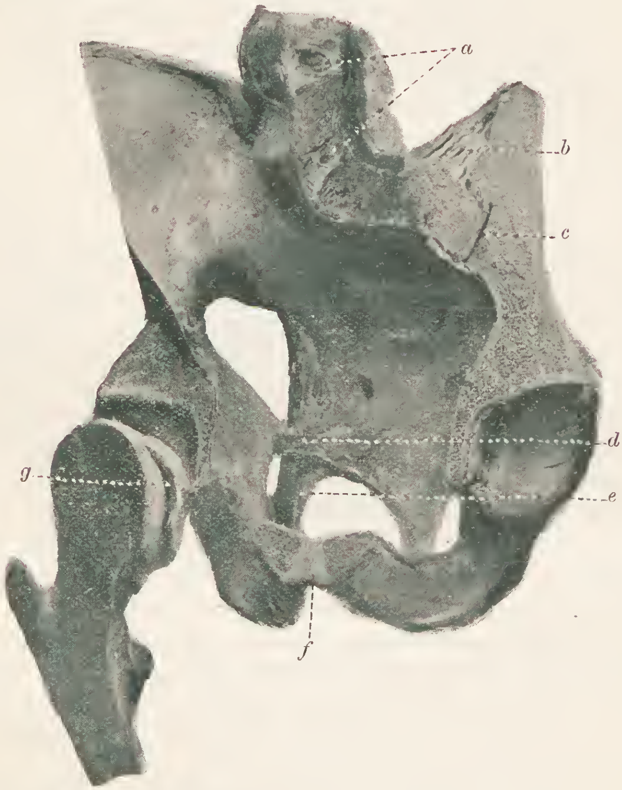


Fig. 179.—Pelvic and Hip-Joints. *a*, Two intervertebral discs divided by a section through the two last lumbar vertebrae and the base of the sacrum; *b*, section of dorsal sacro-iliac ligament; *c*, section through the synovial cavity of the sacro-iliac articulation; *d*, small sacro-sciatic ligament; *e*, great sacro-sciatic ligament; *f*, section of symphysis pubis; *g*, round ligament of the hip-joint. (Section by Allen Thomson.)

The sacro-iliac articulation is a perfect joint, the opposed auricular surfaces of the sacrum and ilium being clothed with articular cartilage, although the inequalities of their faces, and the adhesions and limitations of movement liable to set in with advance of years, misled the older anatomists into thinking that there was but one cartilage, and calling the joint a synchondrosis, as is still sometimes done.

The *ventral sacro-iliac ligament* (*anterior* of books) is a thin layer of short fibres bounding the joint in the whole extent looking towards the cavity of the pelvis.

The *dorsal sacro-iliac ligament* (*posterior* of books) is an extensive and strong mass of fibres descending from the rough and prominent area above the auricular surface of the ilium to end on the tubercles outside the posterior sacral foramina. Its fibres to the lower sacral vertebrae are longer than those to the first and second, and directed backwards.

A *terminal* sacro-iliac ligament extends from the posterior inferior spine of the ilium to the lateral edge of the third and fourth sacral vertebrae. It is not to be confounded, as it usually is, with the dorsal ligament, from which it is distinct not only in function but in disposition, being separated from it by the space between the upper and lower posterior spines of the ilium—a space which is at the end of a channel on the dorsal aspect of the joint, in which no ligamentous fibres occur.

The sacro-sciatic ligaments. These are large flat bands which form an important part of the wall of the pelvis.

The *great sacro-sciatic ligament* arises broadly from the posterior inferior spine of the ilium, the side of the coccyx and the whole lateral border of the sacrum between. Its fibres are gathered together at the back of the ischial tuberosity and are inserted into its inner margin and that of the ramus of the ischium, the lower fibres going further forwards than the upper, and forming a projecting edge continuous with the obturator fascia.

The small sacro-sciatic ligament arises from the greater part of the border of the sacrum in front of the great sacro-sciatic ligament and in close contact with it, and its fibres converge to be inserted into the tip of the spine of the ischium. It divides the space left between the great sacro-sciatic ligament and the innominate bone into an upper and a lower, called respectively the *great* and the *small sacro-sciatic foramen*; the greater giving exit to the pyriformis muscle, with the gluteal artery and nerve above it, and the sciatic and pudic arteries and nerves below it; the smaller giving exit to the tendon of the obturator internus muscle and re-entrance to the pudic artery and nerve.

The symphysis pubis, or *interpubic disc*, is an incomplete joint consisting of fibrous substance loosely disposed toward the centre, sometimes with an irregular space within it, especially in the female. The fibres of the disc take origin from the opposed surfaces covered in young adults with cartilage, and are arranged concentrically; but they are inclosed by fibres attached to the surfaces around, and these are distinguished as superior, inferior, anterior and posterior, names so obviously erroneously applied that they cannot be recommended. Those which follow are at least more correct. The *intrapelvic* ligament is the shortest and least distinct from those of the disc; the *intercristal* ligament is strong, attached to the inner parts of the crests; the *pre-urethral* is still thicker and, especially in the female, rounds the front of the subpubic arch; the *intercrural* ligament (*anterior* of books) occupies the surfaces between the lines of attachment of the fascia lata, and has therefore much longer fibres in the female than in the male, as has also the pre-urethral.

The obturator membrane may be conveniently described in this place; it has, however, no connection with any articulation, but is simply part of the pelvic wall. It is a fibrous septum stretching across the obturator foramen and leaving, opposite the obturator groove of the anterior ramus of the pubic bone, an opening for the passage of the obturator vessels and nerve.

Movements of pelvis. Only in such positions as sitting on the ground or crouching down on the balls of the toes, with the column bent forwards, is the sacrum placed with its base upwards so as to press downwards in the form of a wedge like the keystone of an arch. In the upright position, the ventral borders of the auricular surfaces look directly downwards, the weight of the body falls immediately in front of them, and the dorsal sacro-iliac ligaments are made tense, as is well illustrated in pelvises deformed by rachitis, in which the parts of the innominate bones giving attachment to those ligaments are bent in over the dorsum of the sacrum. The sacral attachments of these ligaments, together with the slight projections of the auricular surfaces of the sacrum, furnish the axis round which the sacrum rotates, the base being pressed down by the weight of the body, and the apex tilting upwards. The upward tilting of the apex of the sacrum tightens the sacro-sciatic and terminal sacro-iliac ligaments, and is limited by them. In its second and third vertebrae the sacrum is wider at the ventral than at the dorsal margins of the auricular surfaces, and the tilting up of the apex slightly separates the iliac bones while the symphysis pubis forms the hinge of the movement. The same movement takes place to a greater extent in parturition, the child's head pressing directly on the apex of the sacrum before pressing the coccyx back. But it is also true that the ligaments of the symphysis are liable to elongate before parturition, and thereby allow a certain enlargement of the brim of the pelvis.

The Hip-Joint.

This is a ball-and-socket joint, the curves of the articular surfaces being spherical or nearly so. Besides a capsule surrounding it, the joint presents a cotyloid and a round ligament within the capsule.

The *cotyloid ligament* is a prominent tough fibrous rim surrounding the acetabulum, its fibres taking origin from the prominent margin of the cup all round, and bridging over the notch by a part distinguished as the *transverse ligament*, in which three sets of fibres can be distinguished, namely, two sets arising from the margins of the notch and decussating, and a third set superficial to them and passing straight across.

The *round ligament* (*ligamentum teres*) is a distinct cord of fibres rounded at its attachment to the pit of the head of the femur, and extending thence down to the margins of the notch and to the deep edge of the transverse ligament, surrounded by a pillar of synovial membrane. It lies in the non-articular part of the acetabulum.

The *fibrous capsule* (*capsular ligament*) is strong in front and on the outer and inner sides, but is weak behind. It does not, when laid bare, allow the opposed surfaces to fall separate, as does the capsule of the shoulder-joint. It arises from the outer surface of the wall of the acetabulum and from the base of the peripheral surface of the cotyloid ligament, as also from the transverse ligament, but leaves the notch uncovered for the passage of articular vessels. It is inserted in front into the whole length of the intertrochanteric line, and externally close to the insertion of the obturator externus muscle; but posteriorly, while it clothes the neck of the femur in the half nearest the head, it has no femoral insertion. The fibres going to the femur from in front of the notch of the acetabulum extend to the

FIG. 180.—LEFT HIP-JOINT from behind in the erect posture. *a*, Fibres from behind the notch of the acetabulum, stretching obliquely upwards and outwards and leaving the neck of the femur bare beyond *b*; *c*, rectus femoris; *d*, insertion of pyriformis; *e*, obturator internus; *f*, gluteus medius; *g*, gluteus minimus; *h*, psoas magnus.

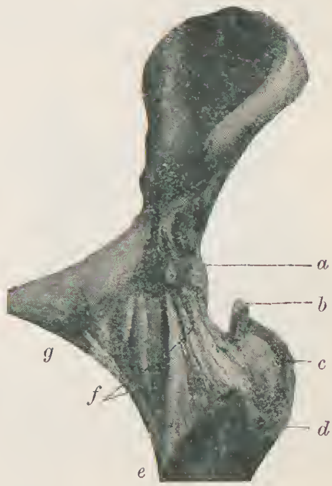


FIG. 181.—LEFT HIP-JOINT from the front, in the erect posture. *a*, Rectus femoris; *b*, pyriformis; *c*, gluteus medius; *d*, gluteus minimus; from *a* to *e*, ilio-femoral ligament; *f*, Bigelow's ligament; from *g* to *e*, pubo-femoral band.

inner end of the anterior intertrochanteric line, and those from behind the notch wind upwards to the trochanteric pit, while in the space between there are none but circular fibres; so that the synovial membrane is left bare where it is reflected from the capsule to the back of the neck of the femur. Several strong bands of fibres strengthening the front of the capsule have received special names. The principal of these is the *ilio-femoral ligament*, arising from the lower part of the anterior inferior iliac spine, directed vertically downwards, so as to cross the neck of the femur obliquely, and inserted into the part of the intertrochanteric line on the inner border of the femoral shaft. The *ilio-trochanteric* fibres arise from the upper margin of the acetabulum, in close contact with the ilio-femora

ligament, and proceed outwards to the tubercle of the outer end of the intertrochanteric line. The **Y**-*shaped ligament of Bigelow* is a term in use among surgeons to indicate by one name the two bands just mentioned; but the important surgical fact is that in dislocation backwards the head of the femur ruptures the capsule behind the outer fibres, and that in dislocation forwards it ruptures it internal to the ilio-femoral ligament, while in both, the fibres radiating from above the acetabulum remain untorn and must be taken into consideration if a dislocation is to be reduced without violence. The part of the capsule internal to the ilio-femoral ligament is thin and occasionally even perforated; but a thicker *pubo-femoral* band proceeds from the pubic margin of the acetabulum, above the notch, and is inserted into the femur behind the ilio-femoral ligament.

The *synovial membrane* extends from the capsule over the free surfaces of the cotyloid ligament. It covers a pad of fat which occupies the non-articular portion of the acetabulum. From the Haversian gland so formed, and from the margin of the transverse ligament, it is continued cylindrically on the ligamentum teres. In front it clothes the whole neck of the femur, but at the back part it is reflected from the capsule to the periosteum, about the middle of the neck. Anteriorly it occasionally communicates internal to the ilio-femoral ligament with the bursa beneath the ilio-psoas muscle.

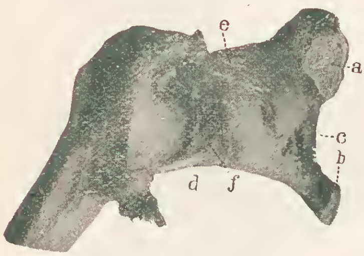


FIG. 182.—LEFT HIP-JOINT from behind in full flexion. *a*, Ramus of ischium sawn across; *b*, superior ramus of pubis, sawn across; *c*, notch of acetabulum; *d*, fibres to the lower end of the anterior trochanteric line; *e*, fibres inserted into the digital fossa; between *d* and *e*, circular fibres; *f*, fold of synovial membrane.

Movements of hip-joint. Being a ball-and-socket joint, the hip-joint allows movement of the limb in every direction. The limits of the different movements are determined partly by the forms of the bones and partly by the ligaments. Thus flexion is limited by locking of the upper edge of the acetabulum on the front of the femur; and in less extreme flexion, adduction and abduction are respectively limited by locking of the anterior and posterior walls of the acetabulum; while over-extension is limited by tension of the whole of the strong anterior part of the capsule. But other limits are put to movement by the thickness of the soft parts and stretching of muscles. Thus the stretched adductor muscles limit abduction of the extended thigh, while, in stout persons, stooping is rendered difficult by the obstructing soft parts.

In the erect posture the fibres of the capsule are stretched by reason of their obliquity, both those in front, against which the femur is pushed, and also the ischial fibres behind on which it pulls, and which are then twisted in exactly the same direction as the tendon of the obturator externus muscle laid against them and aiding them. In flexion

of the thigh the acetabulo-femoral fibres have their two attachments brought opposite one to the other, and are untwisted, while the circular fibres behind are placed on the stretch. Abduction with outward rotation spreads out the fibres of the front of the capsule; flexion with adduction and rotation inwards spreads out the ischial fibres behind.

The round ligament is placed on the stretch in only one position, namely, when a slight degree of flexion is combined with adduction. This can be seen by removal of the deep part of the acetabulum without injuring the ligaments. The position mentioned is that into which the joint is thrown in the extreme of the position called in military drill "standing at ease." In ordinary life the position called "attention" in drill, namely, with the weight of the body equally distributed on the two lower limbs both kept straight at the knee, is rarely made use of; the natural attitude of rest when standing being with the weight principally thrown on one straight limb, while the other is used for balance, and slightly bent; and it is when the maximum of weight is thrown on one limb and the maximum obliquity given to the pelvis that the round ligament comes into use. It is sometimes alleged to be a feeble ligament; but this is never the case in young and healthy joints.

The margins of the acetabulum and articular cartilage of the femur are made parallel in a position combining flexion, abduction and rotation outwards, which is that assumed in sitting cross-legged on the floor. In ordinary circumstances, and especially when the thigh is behind in running, the back of the head of the femur is embedded in the acetabulum, and the fore part exposed and pressed against the capsule. Yet dislocations backwards are far more common than dislocations forwards.

The Knee-Joint.

To understand the knee-joint properly it must be recognized as consisting of three joints intercommunicating, namely, a patellar and an external and internal tibio-femoral. These three joints are distinct, or almost so, in a number of ungulate animals, and are probably always distinct in their first appearance. The two originally separate tibio-femoral joints are hinge-joints, and have each an external and internal lateral ligament; but the internal lateral of the outer joint and the external lateral of the inner joint are called the crucial ligaments, and the others the lateral ligaments of the knee-joint. Further, there is between each condyle of the femur and the tibia a fibro-plate of semilunar form.

The *fibrous capsule* of the knee-joint is strong behind and at the sides, but weak in front. Above the patella, where the joint is covered by the extensor muscles, the capsule is absent. On each side of the patella it is formed above by spreading aponeurotic insertions of the vasti muscles, and, lower down, takes the form of retinacula of the patella.

The *external lateral ligament* consists of two parts. Foremost is the

long external lateral ligament, distinct from the capsule, a rounded cord arising from the external tuberosity of the femur, separated from the tendon and groove of the popliteus by the bursa of that tendon, and inserted below into the head of the fibula, surrounded by the insertion of the biceps muscle, and separated from it usually by another bursa. The *short external lateral ligament* is further back and not distinct from the capsule. It is attached below to the styloid process of the fibula, which also receives other fibres from the back of the capsule.

The *internal lateral ligament* is a long, distinct and strong flat band descending from the internal tuberosity of the femur to be inserted into

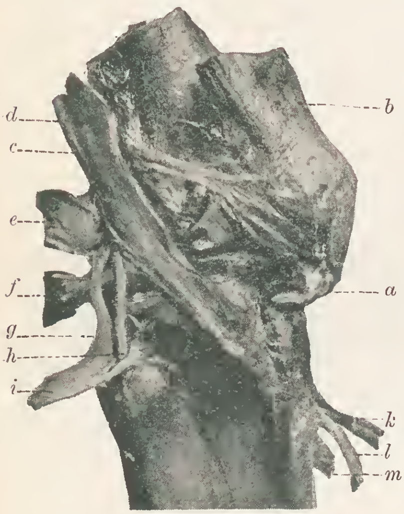


FIG. 183.

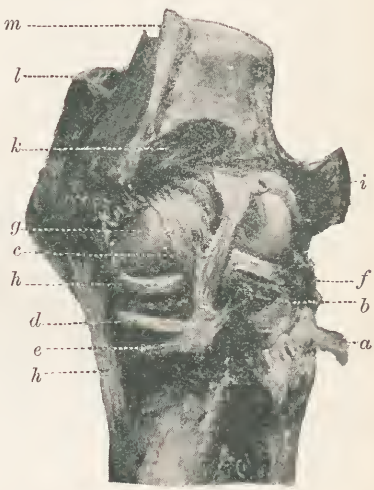


FIG. 184.

FIG. 183.—RIGHT KNEE from outer side. *a*, Patellar ligament; *b*, quadriceps extensor cruris; *c*, external retinaculum of patella; *d*, band of fascia lata pulled on by the tensor fasciae femoris; *e*, outer head of gastrocnemius; *f*, popliteus; *g*, *h*, short and long bands of external lateral ligament; *i*, insertion of biceps; *k*, *l*, *m*, insertions of sartorius, gracilis and semitendinosus.

FIG. 184.—RIGHT KNEE from behind. *a*, Biceps and, below it, the posterior ligament of upper tibio-fibular articulation; *b*, semimembranosus; *c*, its upper band of insertion, called Winslow's ligament; *d*, its middle band of insertion; *e*, its lower band of insertion over popliteus muscle; *f*, tendon of popliteus; *g*, part of the posterior ligament; *h*, internal semilunar disc; *i*, *k*, outer and inner heads of gastrocnemius; *l*, rectus femoris; *m*, tendon of adductor magnus.

a rough surface on the shaft of the tibia, further back than the tendon of the semitendinosus muscle. It crosses and glides on the anterior division of the tendon of the semimembranosus muscle, which lies in the groove of the internal tuberosity of the tibia.

The *posterior ligament* is the strong back part of the fibrous capsule already mentioned, and covers the condyles of the femur. Between the condyles it presents a strong oblique band, long known as the *ligament of Winslow*, taking an upward and outward direction, in great part continuous with the tendon of the semimembranosus muscle, and constituting its upper insertion.

The *ligamentum patellae* is the tendon of insertion of the quadriceps extensor femoris; the patella being a sesamoid bone developed in the tendon. It partakes, however, of the toughness of ligament, and is not liable to snap. It arises from the borders and deep surface of the lower part of the patella, and is inserted into the rough part of the tubercle of the tibia. Between it and the upper part of the tubercle there is an important bursa, liable to inflammation, and more likely to give trouble in diagnosis than is inflammation of the superficial bursa over the patella.

FIG. 185.—RIGHT KNEE from the front, with the capsule removed and the tibia sawn from before backwards between the crucial ligaments. *a*, Tendon of popliteus; *b*, *c*, external and internal lateral ligaments; *d*, *e*, external and internal semilunar discs; *f*, *g*, external and internal crucial ligaments; *h*, ligamentum patellae reflected with portion of patella attached.

The *retinacula* or *lateral ligaments of the patella* are membranous bands, variously described. One, *internal*, passes from the patella to the inner tuberosity of the tibia, while another, *external*, closely connected with the strong band of the fascia lata pulled on by the tensor fasciae femoris, turns downwards to the outer tuberosity of the femur.

The *anterior or external crucial ligament* is attached above to the inner side of the external condyle of the femur near the back, and inferiorly to the tibia in front of the spine.

The *posterior or internal crucial ligament* is attached above to the outer side of the inner condyle of the femur, at the fore part of the intercondylar fossa, and is inserted inferiorly into the popliteal notch.

The *semilunar fibro-plates* (*cartilages or fibro-cartilages* of authors) are crescentic felted structures, each with an upper and a lower free surface, a free edge turned towards the centre of the joint, and a thick peripheral border adherent to the fibrous capsule. They assume the appearance of ligamentous bands at their extremities. They cover the bevelled parts of the tibial surfaces. The *internal fibro-plate* is the more fixed in position, and has its extremities widely separate, the posterior being attached to the rough surface behind the tibial spine, in front of the internal crucial ligament, and the anterior quite in front of the external crucial ligament. The *external fibro-plate* is nearly circular, its extremities being attached near one to

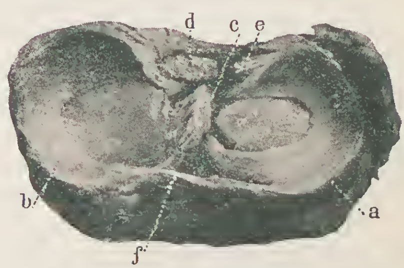


FIG. 186.—HEAD OF LEFT TIBIA supporting *a* and *b*, the outer and inner semilunar discs; *c*, external crucial ligament; *d*, internal or posterior crucial ligament; *e*, accessory band from the external disc to join the posterior crucial ligament; *f*, transverse ligament.

the other, the posterior on the top of the tibial spine behind the external crucial ligament, and the anterior at the outside of the same. At its posterior extremity it is joined by an *accessory ligament* descending from the posterior crucial. It is very freely movable in a backward and forward direction on the tibia, and, on that account, is capable of being dislocated. Anteriorly, the two semilunar fibro-plates are usually united by a *transverse ligament*, a thin bundle of fibres extending between the foremost parts of their convex borders.

The *synovial membrane*, when artificially distended, bulges out between the sides of the patella and the lateral ligaments, and superiorly forms a pouch extending a couple of inches upwards, covered by the crureus muscle, and kept from falling down between the patella and femur by the subcrureus muscle. Beneath the patella, and extending to each side, there is a great pad of fat, from the middle of which a thin pillar of synovial membrane, called *ligamentum mucosum*, extends to be attached to the front of the intercondylar fossa. It is the remains of a septum formed by two synovial membranes placed back to back, which originally separated the outer from the inner tibio-femoral joint. From the sides of the base of the ligamentum mucosum, two more or less sharp folds, the *alar folds* or *ligaments*, extend in such a position as to fit in under the condyles of the femur. Below and behind the ligamentum mucosum the membrane is reflected up in front of the crucial ligaments, and extends on their sides to the posterior wall of the capsule. It covers the upper and under surfaces of the semilunar plates, and is reflected thence to the capsule before reaching the margins of the tibial surfaces. On the side of the external condyle of the femur it is continued over the popliteal groove and deep surface of the popliteus tendon; and, at the back of the inner condyle, it communicates with a bursa between the tendon of the semimembranosus muscle and the inner head of the gastrocnemius, which sometimes becomes distended with glairy substance.

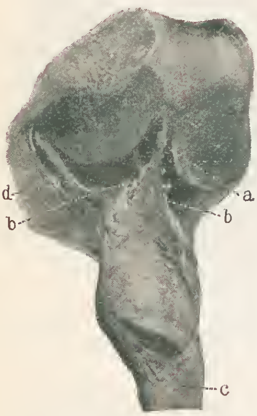


Fig. 187.—Left Knee-Joint laid open and flexed. *a*, Ligamentum mucosum; *b*, *b*, alar folds; *c*, tendon of rectus femoris; *d*, internal fibro-plate or disc.

Movements of the knee-joint. This is a hinge joint. It also allows rotation of the leg when flexed, but not when it is fully extended. When the weight of the body falls on the extended knee, extension is maintained without muscular aid, as is shown by the patella hanging loose; but when the foot is lifted from the ground the patella is involuntarily tightened. In the erect posture the weight of the body falls in front of the knee, and so far from muscular action being required to prevent flexion, over-extension would take place were it not guarded

against by the structure of the joint. In the course of the movement from flexion towards extension, the femoral condyles revolve on the tibia in such a way as to bring successively into contact with the tibia portions of their surfaces nearer the front; and until within a short distance of complete extension their motion is equal, thus throwing the shaft directly forwards. But after the foremost part of the outer condyle has come into contact with the semilunar fibro-plate, the revolving of the inner condyle is continued on its oblique fore part, and turns the front of the shaft inwards. The outer condyle being thus made to rotate on the front of the outer condylar portion of the tibial spine, pushes the part of the external fibro-plate near its anterior attachment over the anterior and inner border of the tibial surface, and is locked firmly against it (Bruce Young). Were it not for the locking of the bones one against the other, the whole tendency to over-extension would have to be resisted by the ligaments and by the flexor muscles; and even with the advantage thus gained, the pressure of the weight of the body is so great that when the muscles of the calf are paralyzed, convexity of the back of the knee sets in. In extension, all the tibio-femoral ligaments are tight, with the exception of the internal crucial, which is tightened in flexion and becomes the pivot round which the leg can be rotated for about 45 degrees. After the knee has been flexed as much as it can be by muscular action, it is always possible to flex it further by lifting the leg with the hand; and it is into this position of extreme flexion that the knee is brought in sinking down on the hams and the balls of the toes. In assuming this position the femur is rotated inwards by the backmost part of the outer condyle coming into play (Goodsir); and the inner condyle, by a facet hitherto unnoticed, presses against the surface of the tibia, twisting up behind the spine.

The patella, in extension, is thrown inwards by the prominence of the outer margin of the patellar surface of the femur, and is guarded from dislocation inwards by its outer retinaculum, and by fibres descending to it from the fascia lata of the outside of the thigh. In flexion it is turned outwards by the projection forwards of the inner condyle of the femur, and is protected from outward dislocation by the tightening of its inner retinaculum over that condyle. The prominence of the knee in flexion exhibits a flat surface with three angles, two to the outside formed by patella and outer edge of the patellar surface of the femur, and one to the inner side formed by the inner condyle.

The different facets of the patella come into contact with the femur in different positions. When the knee is kept extended by the quadriceps extensor, the two lower facets of the patella are in contact with the uppermost part of the patellar surface of the femur. In semiflexion the two middle surfaces only are in contact, while both the upper and lower facets are separated from the femur; and thus it is that transverse fracture of the patella is of so common occurrence as the result of spasmodic

contraction of the quadriceps extensor, when the muscle and the ligamentum patellae pull its upper and lower free extremities back, and the femur presses it forward in the middle. In extreme muscular flexion the upper facets are in contact with the femur; and in complete flexion by sinking the weight of the body on the bent knee, the inner facet of the patella rests on the surface provided for it on the inner condyle.

The Joints of the Leg and Foot.

The superior tibio-fibular articulation is surrounded by a fibrous capsule in which *anterior* and *posterior ligaments* may be distinguished passing upwards and inwards from the fibula. It occasionally communicates with the knee-joint.

The interosseous membrane is a fibrous septum uniting the sharp outer edge of the shaft of the tibia with the prominent line on the inner surface of the fibula. Its fibres are sloped, downwards and outwards. It leaves a considerable opening above, which is traversed by the anterior-tibial vessels.

The inferior tibio-fibular articulation is closely connected with the ankle-joint, and contains within it, prolonged upwards for more than half an inch from that joint, a synovial recess padded with adipose tissue, but without articular cartilage.

Fig. 188.—Dorsiflexed Left Ankle from behind. A, Interosseous membrane; B, posterior ligament of lower tibio-fibular articulation; C, transverse ligament; D, E, posterior and middle bands of external lateral ligament of ankle-joint; F, G, H, astragalar, calcaneal, and scaphoid portions of internal lateral ligament; I, posterior tubercle of astragalus, with posterior astragalo-calcaneal ligament external to the dotted line, and internal astragalo-calcaneal fibres internal to it.

The *anterior inferior tibio-fibular ligament* is a broad band passing upwards and inwards from the front of the external malleolus to the front of the tibia.

The *posterior inferior tibio-fibular ligament* has a superficial part disposed similarly to the anterior ligament, and a deep part with more nearly horizontal fibres stretching inwards from the deep surface of the external malleolus, and lined inferiorly by the synovial membrane of the ankle-joint.

The *inferior interosseous ligament*, extending downwards from the lower end of the interosseous membrane, consists of fibres both in front and behind the synovial recess, but more abundant behind it.

The *transverse ligament of the ankle-joint* is a tibio-fibular band separated from the deep part of the posterior inferior tibio-fibular ligament, as seen from within the ankle-joint, by a fold of synovial membrane. It arises from the deep surface of the external malleolus, and its fibres spread out to be inserted along the posterior inferior edge of the tibia.

The ankle-joint is a hinge joint, with lateral ligaments, which also help to support the joints between the astragalus, calcaneum and scaphoid.

The *internal lateral ligament* is a strong flat band, expanding as it descends from the extremity of the internal malleolus, to be inserted posteriorly into the inner side of the astragalus near the back, further forwards into both astragalus and sustentaculum tali, and in front of this into the inferior calcaneo-scaphoid ligament and the inner side of the scaphoid bone.[1]

The *external lateral ligament* consists of three round bands, each at right angles to both the others. The posterior band extends from the pit on the inner side of the external malleolus inwards and slightly backwards to the posterior surface of the astragalus, and is lined above by the synovial membrane of the ankle-joint, and below by that of the posterior astragalo-calcaneal joint. The middle band passes directly downwards from the extremity of the external malleolus to the outer side of the calcaneum, and is lined by the synovial membrane of the posterior astragalo-calcaneal joint alone. The anterior band extends from the front of the external malleolus forwards and inwards to the astragalus in front of its upper articular surface, and is lined by the synovial membrane of the ankle-joint alone.

Anterior and posterior ligaments of the ankle-joint are described, but consist of mere thin fibrous expansions supporting the synovial membrane.

The *synovial membrane* is prolonged up between the tibia and fibula, and is cushioned with fat in front and behind, as well as between the bones.

The tarsal and tarso-metatarsal articulations form a series of closely connected joints with a number of synovial cavities. *The posterior astragalo-calcaneal* articulation is behind the interosseous ligament uniting these bones, and has a separate synovial membrane: the *astragalo-calcaneo-scaphoid* articulation has a second, and the *calcaneo-cuboid* articulation a third. Three other synovial cavities are bounded by *tarsals* and *metatarsals*, viz., one peculiar to the articulation between the internal cuneiform and first metatarsal bone, with a distinct fibrous capsule round it; another between the cuboid and fourth and fifth metatarsals, extending between the bases of those metatarsals; and a third which is common to the articulations of the cuneiforms one with another and with the scaphoid, cuboid and second and third metatarsal bones, and extending between the bases of the second, third and fourth metatarsals.

Besides the more membranous dispositions of fibrous tissue over synovial sacs, the following important ligaments are found in connection with these articulations:

The *interosseous astragalo-calcaneal ligament* is attached above to the deep

[1] This ligament is often described as if only its posterior fibres were attached to the astragalus. But when the joint is cut open they can be seen inserted all along the inner side of the joint below the articular surface for the internal malleolus. The attachment to the sustentaculum tali is not very strong, and may even be absent.

groove beneath the astragalus, and below to the corresponding groove on the calcaneum, and consists of a large number of vertical fibres arranged in a broad band, to the fore and inner side of the posterior astragalo-calcaneal articulation, between it and the astragalo-calcaneo-scaphoid. The anterior and outer extremity of this ligament divides in front into two sets of strong fibres, one forming the outer part of the capsule of the astragalo-calcaneo-scaphoid joint, and the other the anterior part of the

FIG. 189.—DORSUM OF STRETCHED LEFT FOOT WITH THE OUTER SIDE DEPRESSED. A, Anterior ligament of lower tibio-fibular articulation; B, head of astragalus crossed by C, portion of superior astragalo-scaphoid ligament; D, scaphoid; E, internal cuneiform; F, base of second metatarsal; G, external cuneiform; H, I, anterior and middle bands of the external lateral ligament of the ankle-joint; K, anterior and outer fibres of interosseous astragalo-calcaneal ligament. They abut against the joint in front, while the posterior and outer fibres seen between K and H lie against the joint behind; L, cuboid surface of calcaneum laid bare by the rotation downwards of the cuboid; M, anterior part of cuboid bone, with ligaments extending to external cuneiform and fourth and fifth metatarsals.

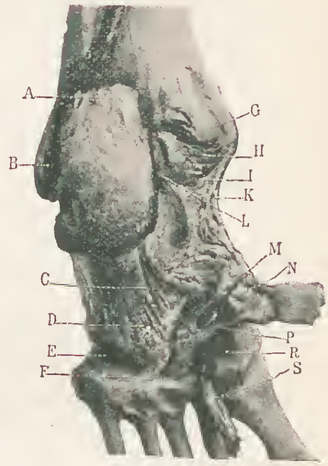


FIG. 190.—PLANTAR VIEW OF STRETCHED LEFT FOOT. A, Tendo Achillis; B, groove for peroneal tendons; C, short plantar ligament; D, long plantar ligament; E, groove for peroneus longus; F, ligament from the fifth to other metatarsal bones; G, groove for tibialis posticus; H, I, K, the three portions of the internal lateral ligament of the ankle-joint; L, groove for the flexor longus hallucis passing from astragalus to sustentaculum tali; M, scaphoid attachment of inferior calcaneo-scaphoid ligament; N, tuberosity of scaphoid with tendon of tibialis posticus standing out; P, band from tuberosity of scaphoid to external cuneiform; R, internal cuneiform; S, tendon of peroneus longus.

capsule of the posterior astragalo-calcaneal joint. The posterior and inner extremity of the interosseous ligament is continuous with strong fibres placed horizontally between the under surface of the posterior extremity of the astragalus and the edge of the calcaneum posterior to the sustentaculum, and called the *internal ligament of the posterior astragalo-calcaneal joint*: and this again is continuous with vertical fibres constituting the *posterior ligament* of the same joint and strengthening its capsule; but the external part of the capsule is weak.

The *inferior calcaneo-scaphoid ligament* is a strong flat ligament supporting the weight falling on the inner three toes. It is covered superiorly with

synovial membrane, and extends from the anterior margin of the sustentaculum tali, beneath the head of the astragalus, to the scaphoid bone, to be attached close to its posterior articular surface, between it and the tuberosity, and further outwards. It is supported below by the insertion of the tibialis posticus tendon.

The *external calcaneo-scaphoid ligament* is continuous with the outer part of the preceding. It has very short fibres, being attached posteriorly to the superior margin of the anterior extremity of the calcaneum, and lies against the inner side of the capsule of the calcaneo-cuboid joint, with an upper edge exposable from above.

The *inferior calcaneo-cuboid* or *long* and *short plantar* ligaments resist pressure falling on the outer arch of the foot. The *long plantar* ligament consists of a long and strong band extending back nearly to the tubercles of the calcaneum, and inserted in front into the ridge of the cuboid. The *short plantar* ligament, internal to and continuous with the outer edge of the long plantar, is inserted into the inner and back part of the under surface of the cuboid, and especially into its conical process.

Other plantar ligaments exist further forwards. Four bands start from the tuberosity of the scaphoid bone, receiving additional fibres from the tendon of the tibialis posticus muscle, and extend to the three cuneiform bones and the cuboid; that to the internal cuneiform being much the strongest, and that to the external cuneiform the next strongest. From the anterior and outer angle of the internal cuneiform a constant ligament passes to the bases of the second and third metatarsals; and from the under surface of the base of the fifth metatarsal another extends inwards to the bases of the third and fourth; while, in front of these, the adjacent edges of the bases of the four outer metatarsals are united by three bands.

Interosseous ligaments unite the three cuneiforms and the cuboid, as also the four outer metatarsals, one with another, and the second metatarsal with the internal cuneiform.

Dorsal ligaments of capsular character pass, one over the head of the astragalus to the scaphoid, and another so as to cover-in the calcaneo-cuboid articulation. Others, in the form of distinct bands, radiate from the dorsum of the scaphoid to the three cuneiforms and the cuboid. Smaller limited dorsal ligaments, transverse, longitudinal and oblique, unite the cuneiforms and cuboid one with another and with the four outer metatarsals, and the bases of the metatarsals one with another.

A *transverse metatarsal ligament* loosely unites the heads of the five metatarsal bones together.

The metatarso-phalangeal and interphalangeal articulations are similar to the corresponding joints in the upper limb. The first metatarso-phalangeal joint is complicated by two large sesamoid bones in the insertions of the short flexor of the great toe; these are faced with cartilage and united by transverse fibres which glide on the ridge separating the two grooves on the head of the first metatarsal bone.

Movements of the ankle and foot. At the *ankle-joint*, movement is restricted to one path, and its extent, from extreme dorsiflexion to the nearest approach allowed to straightening of the foot into a line with the leg, is not more than quarter of a circle. In standing at attention, the tibia rests on the middle of the opposed surface of the astragalus; and starting from this position, about equal extents of dorsiflexion and straightening are allowed. The axis of revolution is oblique, nearly corresponding with tips of the two malleoli; and the external malleolus being placed lower than the internal, the outer edge of the foot is, to a certain extent, turned downwards in straightening, and upwards in dorsiflexion. This can be made apparent by placing the feet with the ankles and also the balls of the great toes pressed closely together, and rising on tip-toe, when the ankles will be found to separate slightly, and the heels to come nearer one to the other; while, in sinking on the haunches, the knees become parted to a certain extent by compulsion. In straightening the ankle, the obliquity of the axis of revolution necessarily causes the back part of the outer edge of the upper surface of the astragalus to be pressed against the fibula, pushing it away from the tibia and bringing the angular facet of the astragalus into contact with the stretched deep part of the posterior inferior tibio-fibular ligament. In dorsiflexion, the broad fore part of the astragalar surface sweeps back into the space between the malleoli, tightening the anterior inferior tibio-fibular ligament by pushing the external malleolus outwards from the front. Thus spring is given to the ankle-joint by the mobility of the fibula; and this is the only purpose served by the lower tibio-fibular articulation. The fibula is, however, more mobile at its head; and this is probably to allow the inward movement of the tibia relatively to the femur in incipient flexion of the knee.

Between calcaneum and astragalus there is only one path of movement, and it is pivoted round the inner fibres of the interosseous ligament. When the weight of the body falls on the foot, whether the heel be on the ground or raised, the surfaces of the posterior astragalo-calcaneal joint lie in perfect apposition; so also do the surfaces of the astragalo-calcaneo-scaphoid articulation, with the exception of the outer part of the facet on the fore-end of the calcaneum, which is not in use; and the upper margins of the scaphoid and head of the astragalus lie alongside one of the other, while the calcaneo-scaphoid ligaments are on the stretch. When the foot is straightened as nearly as possible into a line with the leg, its outer border is at the same time turned downwards with an inward sweep already begun to a slight extent at the ankle-joint, but carried out by the calcaneum and scaphoid moving on the astragalus. In this movement, the surfaces of the posterior astragalo-calcaneal joint are no longer in apposition, but the outer edge of the calcaneal surface moves downwards and forwards from beneath the body of the astragalus, and only the anterior part of the astragalar surface is in contact with the

calcaneum, a gap being left behind: a similar want of conformity is brought about between the sustentacular facet and the head of the astragalus; while the outer part of the facet above the fore-end of the calcaneum glides into contact. Also by the same rotation the calcaneum pulls on the external calcaneo-scaphoid ligament, and makes the scaphoid revolve on the *head of the astragalus*, so that the latter projects by its upper and outer part on the dorsum of the foot, while the tension of the inferior calcaneo-scaphoid ligament is relieved. The turning down of the outer edge of the foot is continued by the movement of the *calcaneo-cuboid* articulation, which is one of rotation of the cuboid round its conical process; and in front of the cuboid bone, it is carried still further by the *fourth and fifth metatarsal bones.* It is easy to understand how in this position arrest of the heel in slipping forwards may lead to dislocation of the astragalus.

The movements of the *metatarso-phalangeal* joints have been subject to much misapprehension. In undeformed feet the great toes lie in contact in their whole length when the heels and balls of the great toes are placed together on a perfectly flat surface. But the path of movement of the toes in over-extension is not upwards, but upwards and outwards (Cleland, 1888) round a cone formed by the series of heads of metatarsals. In consequence of this the great toes separate when raised; and it is in conformity with this that in worn moccasins and in well made shoes the inner edge of the sole turns outwards at the great toe.

In standing, and still more on raising the heel, as in standing on tip-toe, or running, the weight of the body tends to flatten both the longitudinal and transverse arches, and makes the foot for the moment both longer and broader; the ligaments by which these arches are supported are made tense, and the relief of this tension on raising the foot from the ground gives spring to the step.

In running, the weight falls first on the ball of the great toe, and is then quickly distributed to the others. In walking bare-foot, especially if the body be inclined forwards, the same order of events occurs and is followed by the heel reaching the ground and receiving part of the weight, while conversely the heel is raised from the ground first, and the great toe last; but in walking with boots on, the heel is put at once to the ground.

THE BONES OF THE LIMBS COMPARED.

Though many conflicting theories have been advanced as to the relationship of the upper and lower limbs, which cannot be even alluded to in a text-book, and though the subject cannot be fully discussed without copious reference to comparative anatomy as well as embryology, there are certain points which may be shortly mentioned for the guidance of inquiry.

The scapula undoubtedly corresponds with the ilium. It extends in a dorsal direction from the shoulder-joint, its blade is covered by dorsal muscles, and from the blade there passes to the surface the spine, ending at its ventral extremity in the acromion. The ilium, in like manner, extends in a dorsal direction from the hip-joint, and its only superficial part is the crest, ending ventrally at the anterior superior spinous process. The clavicle stretches ventrally from the acromion towards the middle line, and, in like manner, Poupart's ligament stretches ventrally towards the middle line from the anterior superior spinous process. The coracoid is in monotremata and non-mammalian vertebrates a distinct bone extending ventrally from the shoulder-joint, in continuity with the blade of the scapula; and in both monotremata and other animals another element lies at the same depth, proserial to the coracoid, namely, the precoracoid. In the lower limb two deep elements are, in like manner, found on the ventral aspect of the hip-joint, namely, the ischium and os pubis, the os pubis being proserial to the ischium, and therefore corresponding with the precoracoid of monotremata, while the ischium is homologous with the coracoid.

The femur corresponds obviously with the humerus; but no one seems to have noted what is nevertheless evident on comparison of early stages of development, that the outer epicondyle of the humerus and the patellar surface of the femur are similarly situated from their earliest development, being placed on the aspect furthest from the mesial plane of the body, and continuous with the dorsum of the embryo.

In the forearm the radius is the proserial element, and the ulna the retroserial; while in the leg the tibia is the proserial element, and the fibula the retroserial. In the monotremata the head of the fibula is prolonged upwards in the same manner as the olecranon of the ulna.

The thumb and the great toe are the proserial digits of hand and foot respectively. The metatarsal articulations of the four anterior tarsal bones correspond very closely with the metacarpal articulations of the lower range of carpal bones. The pisiform bone is much more developed in many animals than in the human subject; and in the bear it presents an epiphysis exactly similar to another on the tuberosity of the calcaneum, while the bulk of the calcaneum is seen to correspond obviously with the combined pisiform and cuneiform bones of the carpus.

DEVELOPMENT OF THE LIMB BONES.

The skeleton in both the upper and lower limb makes its first appearance, I find, as a single block of cartilage distinct from the axial skeleton; and from this all the bones are developed, the clavicle excepted. In the upper limb, the scapula, humerus, forearm and hand can all be distinguished, forming a continuous mass of embryonic cartilage in which lines afterwards appear in the situation of the joints; and similarly, in the lower

limb, the pelvis, thigh, leg and foot are from one original mass. The radius and ulna are at first similar in size at the wrist; they are bent forwards at the elbow, the radius in continuity with the front of the humerus, and the ulna with the back part. I find also that the tibia and fibula are, at the knee, bent similarly forwards towards the head of the embryo, and that the heel at an early period projects on the fibular or retroserial margin of the foot.

Among the carpal cartilages at first laid down there has been noted one corresponding to the os centrale found in many mammals. It has been found to disappear by fusion with the scaphoid, usually before the end of the third month (p. 146, footnote).

Ossification.

Upper limb. The *clavicle* is of all the bones in the body that in which osseous deposit first appears. This occurs when the embryo is about two-thirds of an inch long and is supposed to be about six weeks old. I find the clavicle existing as a cartilage prior to the commencement of ossification, though it is often described as of purely membranous origin. It is allowed to be cartilaginous at its extremities in later development. About the eighteenth year or later an epiphysis appears which is incorporated with the shaft by the twenty-fifth year.

The *scapula* begins to ossify about the eighth week from a centre at the neck. The coracoid process shows an osseous centre of its own in the first year, and is joined to the rest of the bone about the twelfth or fourteenth. A separate little centre, called subcoracoid, begins in contact with the ununited coracoid centre immediately above the bicipital tubercle, and may extend thence over the whole glenoid cavity. Also a separable scale may occur on the coracoid at the attachment of the coraco-clavicular ligament, and a distinct epiphysis at the tip of the process. The acromion is in part or altogether ossified from one or two separate centres which do not appear till near puberty, but soon spread to form an epiphysis which retains its independence for a considerable time. Along the base of the scapula a narrow cartilaginous strip corresponding with the suprascapular cartilage of hoofed mammals continues through adolescence. It becomes ossified from two centres, one at the inferior angle, and the other commencing opposite the inner end of the spine, both of them appearing later than the acromial centres and uniting to form an epiphysis distinguishable till the twenty-fifth year.

Fig. 191.—Young Scapula. *a*, Acromion with epiphysis apparently formed from two centres of ossification; *b*, coracoid as yet ununited and, below it, the glenoid cavity covered by an extension of the subcoracoid centre; *c*, small epiphysis at tip of coracoid; *d*, position of occasional small centre; *e*, suprascapular strip of cartilage.

The *humerus* begins to ossify in the shaft about the eighth week. It presents in later growth a superior and inferior epiphysis, besides a separate epiphysis of the internal epicondyle. The superior epiphysis has two or more centres of ossification—one in the head, beginning in the first year; one in the great tuberosity, beginning in the third, and sometimes one in the small tuberosity, appearing later. These nuclei join together about the sixth year. At the lower end of the bone there are four centres of ossification, the largest in the trochlea, another in the capitellum, and two others in the epicondyles, all appearing from the third to the fifth year. The trochlear, capitellar and external epicondylar centres unite about the seventeenth year to form the inferior epiphysis, while the internal epicondyle remains ununited for a little longer. The superior epiphysis is not united to the shaft till the twentieth year.

FIG. 192.—YOUNG HUMERUS, with trochlear, capitellar and external epicondylar centres united together, while the internal epicondylar is separate, as is also the superior epiphysis.

The *radius* and *ulna* begin to ossify in the middle of the shaft about the eighth week, and each has an upper and a lower epiphysis; but these are very different in size and in date of appearance. In the radius the large lower epiphysis makes its appearance about the end of the second year, while that of the head is fully three years later. In the ulna the lower epiphysis begins to ossify in the fourth or fifth year, while, at the upper end, the diaphysis is continued right up to the elbow, where it is tipped by a very small epiphysis which does not appear till the tenth year. In both radius and ulna the superior epiphysis is united to the shaft about the seventeenth year, and the inferior not till the twentieth year.

The *carpus* has one centre of ossification for each bone. Those for the os magnum, unciform and cuneiform appear in succession in the first, second and third years respectively; those for the trapezium and semilunar in the fifth year; those of the scaphoid and trapezoid about the sixth or seventh year respectively; and lastly the pisiform, so late as the twelfth year.

The *metacarpals* show ossification in their shafts soon after the radius and ulna, and the distal *phalanges* follow them before the others. The four inner metacarpals have manifest epiphyses at their distal ends, appearing from the third to the fifth year, and remaining distinct till the eighteenth or twentieth year. The phalanges have each an epiphysis at the proximal end, appearing later and uniting earlier than the metacarpal heads. The metacarpal of the thumb resembles the phalanges in having a distinct epiphysis at its base, appearing early and remaining long distinct, but it often shows evidence of a fugitive epiphysis at its distal end. Conversely, traces of proximal epiphysis may be found in some of the other metacarpals.

Lower limb. The *innominate bone* presents one principal ossific centre in each of its three elements; that of the ilium appearing about the ninth week of foetal life, that of the ischium in the third month, and that of the pubic bone in the fourth or fifth month, all three radiating from the acetabulum. Those of the ischium and pubic bone unite below the obturator foramen during the first year after birth, while a Y-shaped cartilage continues to separate them at their acetabular extremities, one from the other and both from the ilium. In this cartilage irregular centres of ossification appear about the twelfth year, and sometimes unite into one piece before uniting with the main bones; but more frequently fail to come into contact one with another, and are least developed between ischium and pubic bone, and most extensive between pubic bone and ilium, where a large intercalar ossification, which has attracted the attention of Albinus and subsequent writers, and been distinguished as *os acetabuli*, may completely overlay the pubic bone. The acetabulum is completed about the eighteenth year. An epiphysis ossifying from more than one nucleus extends along the whole crest of the ilium, and others are formed on the anterior inferior iliac spine and the ischial tuberosity. They appear after puberty, and disappear before the twenty-fifth year, the ischial more slowly than that of the iliac crest. Growth continues at the symphysial surface in the female after these epiphyses have become fixed, and separate nodules of ossification may be seen in this situation; while in the male this surface becomes close grained and smooth at an earlier date.

FIG. 193.—RIGHT INNOMINATE BONE OF TWELFTH YEAR, outer side, showing the epiphyses in the acetabulum. (For the deep side see Fig. 161.)

The *femur* commences to ossify about the end of the second month, earlier than the ilium and humerus. Ossification extends from the shaft up to where the neck joins the head; but for months after birth there is continuous cartilage from the head to the great trochanter. The epiphysis at the lower end appears about the time of birth, and its development extends as high as the tuberosities. In the first year an epiphysis appears in the head; in the fourth year, one in the great trochanter; and, about puberty, another in the small trochanter. This last is the first to disappear: the head is united about the eighteenth year, and the great trochanter soon after it, while the lower epiphysis continues separate till about the twenty-second year.

FIG. 194.—RIGHT FEMUR APPROACHING THE FULL SIZE, with the epiphyses of the head, the two trochanters and the lower end still distinct.

The *patella* begins to ossify in the third year.

The *tibia* begins to ossify about the same time as the femur, and the *fibula* soon after. Each has an upper and a lower epiphysis. The upper epiphysis of the tibia is large, including the tuberosities and descending in front to include that part of the tubercle covered by the bursa, but not the portion on which the ligamentum patellae pulls. It makes its first appearance at the time of birth, and the part for the tubercle may have a separate nucleus. The upper epiphysis of the fibula does not appear till the third or fourth year. The lower epiphyses of these bones unite after the eighteenth year, and the upper about the twenty-second.

Fig. 195.—Right Tibia and Fibula approaching the full size, with their epiphyses still distinct.

It will be remarked that while the bones of the arm and forearm have those epiphyses first united to the shaft which abut on the elbow, it is at the ends furthest from the knee-joint that the epiphyses of the femur and leg-bones first become united; and it has been noted in connection with this that the arterial foramina of the bones of the upper and lower limbs are in opposite directions, pointing the artery to the seat of earlier ossification.

In the *tarsus* the only bone with an epiphysis is the calcaneum. This bone shows its principal nucleus in the sixth month, and its epiphysis about the tenth year. Ossification appears in the astragalus about the seventh month, in the cuboid about the time of birth, in the external cuneiform in the first year, in the internal cuneiform about the second year, in the middle cuneiform about the third year, and in the scaphoid about the seventh year.

The *metatarsals* and phalanges are similar in development to the corresponding bones of the hand; but they are a little later in beginning to ossify.

III. THE SKULL.

The skull is divisible into the cranium, or portion surrounding the brain, and the face. The lower jaw or mandible is articulated with the cranium by means of a pair of complete or synovial articulations. The rest of the skull consists of portions which, even after maceration, are immovably fitted together, but remain ununited by osseous continuity for very different lengths of time. It is very much a question of convenience what portions are to be considered as separate bones; but, with some exceptions, the parts which are generally so recognized are each united into one mass in the young adult, and still separable from others. The cranial bones are counted as eight, viz., the occipital, the two parietals, the frontal, the sphenoid, the ethmoid, and the two temporals. The

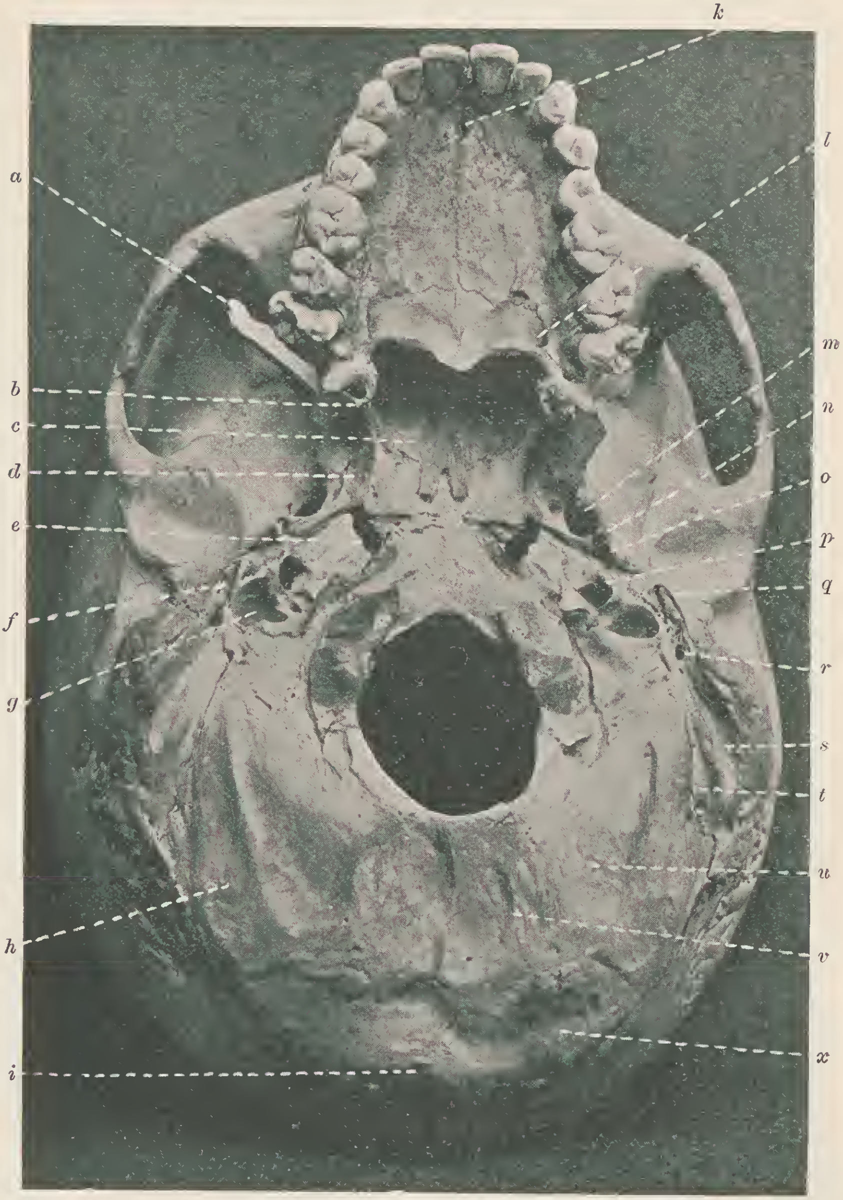


FIG. 196.—BASE OF SKULL. *a*, Spheno-maxillary fissure, with roof of orbit seen through it; *b*, hamular process of internal pterygoid process; *c*, vomer and palatal in contact; *d*, scaphoid fossa; *e*, foramen lacerum medium; *f*, spinous process of great wing of sphenoid; *g*, foramen lacerum posticum; *h*, attachment of obliquus capitis superior; *i*, external occipital protuberance; *k*, anterior palatine canal; *l*, posterior palatine canal; *m*, foramen ovale; *n*, foramen spinosum; *o*, groove for Eustachian tube; *p*, carotid canal; *q*, styloid process; *r*, stylo-mastoid foramen; *s*, digastric groove; *t*, occipital groove; *u*, *v*, attachments of rectus capitis posticus major and minor; *x*, attachment of complexus.

bones belonging wholly to the face are fourteen, of which twelve are in pairs, viz., the superior maxillaries, the palatals, the malars, the nasals, the lachrymals and the inferior turbinated; while two are mesial, viz., the vomer and the mandible. But it may be observed that the ethmoid takes only small part in the wall of the cranium, and is mainly developed in connection with the nasal fossae. The whole deep surface of the cranial wall has a peculiarly close-grained texture which, both from its glossy appearance and the way in which it cracks when exposed to violence, is termed the *vitreous table*, in contradistinction to the *outer table* formed of ordinary compact osseous tissue, and to the intervening cancellated tissue called the *diploe*.

THE OCCIPITAL BONE.

The occipital bone forms the most prominent part of the back of the skull, and enters considerably into the base or inferior aspect. It consists, at birth, of four pieces corresponding with the permanently distinct supra-occipital, basi-occipital and exoccipitals found in fishes and reptiles. These are united, and inclose the large oval opening, *foramen magnum*, through which the medulla oblongata or lowest part of the brain passes, surrounded by its investments, to be continuous with the spinal cord. The part in front of the foramen magnum is called the *basilar process*; it increases in thickness from behind forwards, and is so completely united with the sphenoid bone, after the twentieth year, that no mark is left of the place of union, and the two bones can only be separated by means of the saw, a circumstance which led Sömmering to describe the sphenoid and occipital as one bone, under the name of *basilar bone*.

Borders. The occipital bone is lozenge-shaped, its upper two borders being united with the two parietals by means of a deeply serrated suture called *occipito-parietal* or *lambdoidal*, and its lateral angles fitting in between the parietal bone and the mastoid portion of the temporal on each side; while its inferior borders are separated below by the extremity of the basilar process, and are each divided into two parts, the upper articulating by a not very deeply serrated suture with the mastoid portion of the temporal bone, and the lower in contact with the petrous portion of the temporal bone by a thin edge running along the side of the basilar process. At the point of union between these two divisions of the lower border, a projection, *the jugular process*, fits by means of a rough summit into the retreating angle between the petrous and mastoid portions of the temporal, and is bounded in front by a smooth concavity, the *jugular notch*, which, together with an irregular part of the edge internal to it, forms the posterior limit of a foramen between the occipital and temporal bones, named *foramen jugulare* or *foramen lacerum posticum*, transmitting by its outer and more regular part the internal jugular vein, and by its

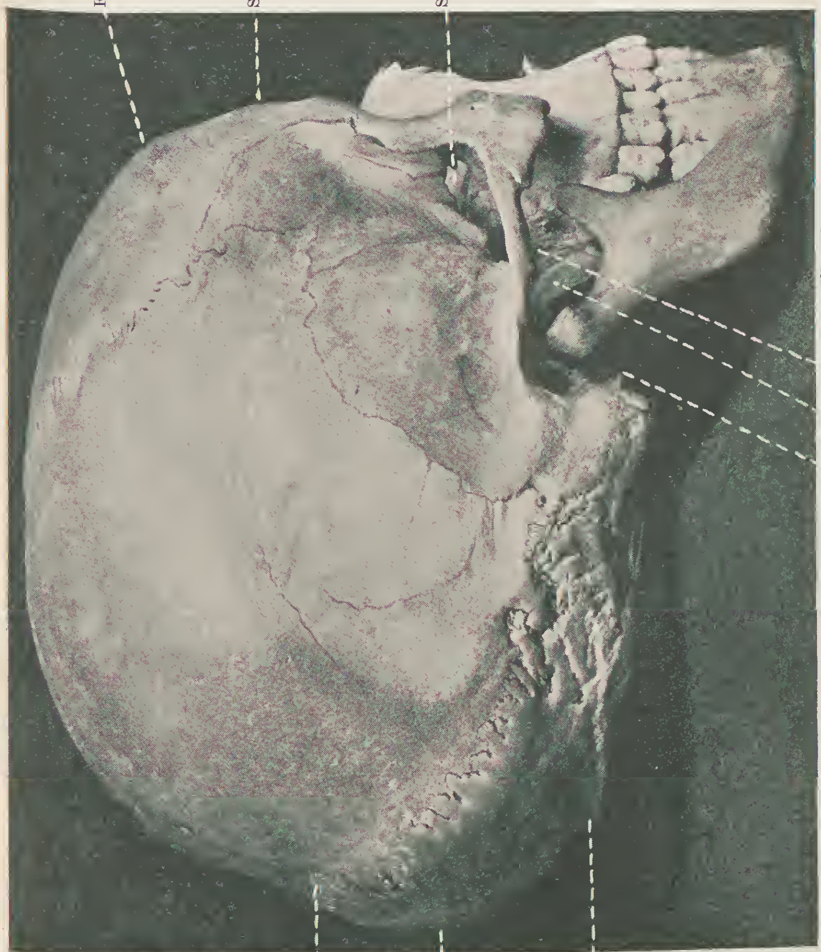


Fig. 197.—Right Side of Skull, slightly from behind. Young adult female.

inner part three nerves, the glosso-pharyngeal, the vagus or pneumogastric, and the spinal accessory.

The **deep surface** presents, about midway between the lateral angles, a prominence, the *internal occipital protuberance*, to which converge four prominent lines from the superior and lateral angles and the back of the foramen magnum, separating one from another the two *superior* and two *inferior occipital fossae*, on which rest the posterior cerebral lobes and the lobes of the cerebellum respectively. The inferior line (*internal occipital crest*) is a simple ridge giving attachment to the falx cerebelli, but the others are grooved, and correspond in position with two venous sinuses in the dura mater, as the fibrous membrane is called which performs the office of periosteum and forms the outermost envelope of the brain. The upper groove marks the position of the terminal part of the superior longitudinal sinus, which pours its blood into the lateral sinuses, two channels coursing outwards on the transverse grooves, and destined, after curving down on the parietal and temporal bones, each of them to mark the occipital with a second and deeper groove, directed inwards behind the jugular process, and forwards to the jugular notch. The basilar process is hollowed longitudinally by the *basilar groove*, on which lies the medulla oblongata, and is bevelled at the margin, where the edge of the inferior petrosal sinus rests. Passing backwards from the sides of the basilar groove, a pair of eminences mark the places of junction of the basi-occipital and exoccipital elements, and are continued thence as ridges round to the back of the foramen magnum. These supraforaminal ridges form, when clothed with the dura mater, the upper limit of the funnel leading down into the spinal canal. Inside and behind the ridge, beneath the eminence, there is situated on each side the inner orifice of the *anterior condyloid foramen*, through which the hypoglossal nerve passes in a direction downwards, forwards and outwards; while, external to the ridge, there is placed the deep orifice of the *posterior condyloid foramen*, an aperture not always present, by which a vein passes upwards, forwards and outwards from behind the condyle, to end in the lateral sinus (Fig. 221).

The **superficial surface** presents, at a spot nearly opposite the internal protuberance, a projection called the *external occipital protuberance*, the mesial point whence curves outwards to the lateral angles the *superior curved line*, corresponding with the more prominent ridge, or transverse crest, which in the lower animals separates the cervical aspect from the roof. A mesial ridge (*external occipital crest*) passes from this to the foramen magnum and is crossed by an *inferior curved line* extending outwards and forwards to the jugular processes. The part above the superior curved line is smooth, and the middle of its convexity is called the *occipital probole.* The superior curved line is itself expanded more or less distinctly in young subjects and some adults, into an area giving an attachment internally to the trapezius muscle, and externally to the splenius and sterno-cleido-mastoid, while its upper limit gives origin to

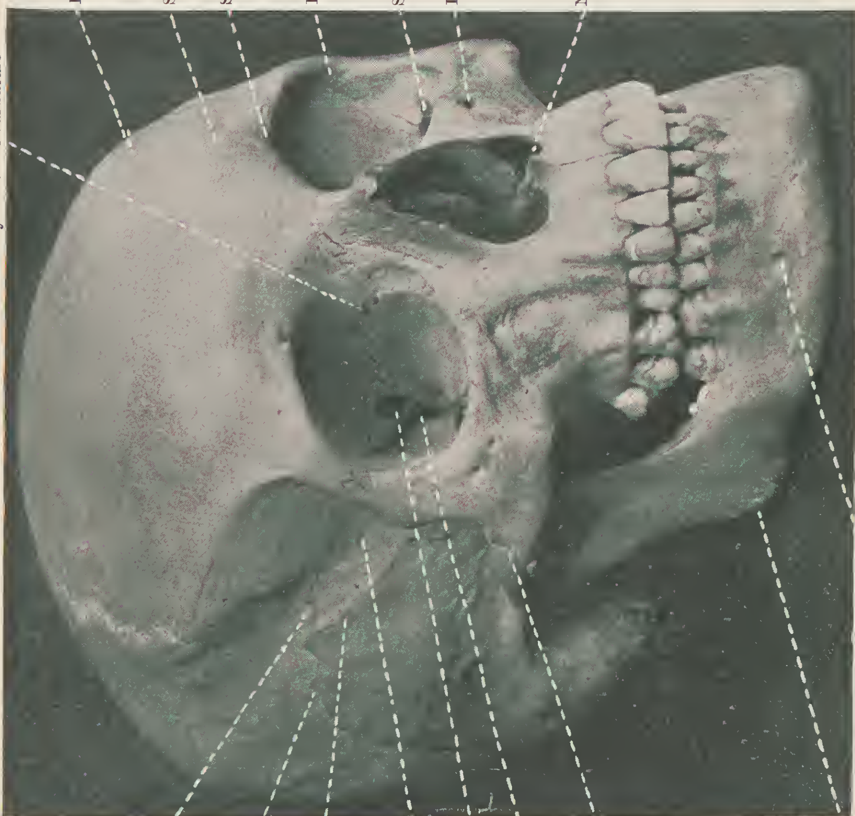


Fig. 198.—Skull from front and right side.

the occipitales muscles and the thin aponeurosis between them. The part between the curved lines presents on each side of the crest a large depression for the complexus muscle, rough in its lower part for a deep-seated tendon; and further outwards a less distinct longitudinal depression marking the insertion of the obliquus capitis superior. Below the inferior curved line are two other depressions, the inner for the rectus capitis posticus minor, and the outer for the rectus capitis posticus major. The articular *condyles* lie to the sides of the anterior half of the foramen magnum; behind them are the *posterior condyloid foramina* already mentioned, one or both of which may be absent, and in front, close to where the outer margins of the condyles curve inwards, are the exits of the anterior condyloid foramina, also already mentioned. Extending from condyle to jugular process behind the jugular notch is a rough prominence giving attachment to the rectus capitis lateralis; and this prominence has a certain interest as the representative of the paroccipital process which in various animals, as the pig and the sheep, is greatly elongated to give attachment to the muscles which in man are inserted into the mastoid process. The inferior surface of the basilar process presents in the middle the *pharyngeal tubercle*, giving attachment to the occipital ligament of the pharynx, and on each side of this a line in front of which the rectus capitis anticus major muscle is inserted, while behind and further out is placed the insertion of the rectus capitis posticus minor.

The condyles for articulation with the atlas have their posterior extremities opposite the middle of the foramen magnum, and curve inwards as they pass forwards on each side of it. They are convex both longitudinally and transversely, with their inner margins prominent, and might seem to lie in the circumference of a sphere, but on close inspection are seen to be traversed by an oblique line of greatest convexity, dividing each into an anterior and posterior facet corresponding with the basilar and posterior parts which lie at right angles in a dog or a sheep. Internal to them are two rough impressions, the attachments of the lateral odontoid ligaments. The fore parts of the condyles are projected in the adult on two short wedges of support, beyond the level of the foramen magnum. These wedges are absent at birth, and tend to disappear in old age, and are connected with the balance of the head on the column, being developed proportionately to the increase of weight of the forehead and face.[1] The condyles are much flatter at birth, and often flattened in old age. They are comparable with the superior articular surfaces of the axis in respect that they are completed in front by the mesial element, the basi-occipital, which has within it, in foetal life, the notochord.

[1] Cleland, *Philosophical Transactions*, 1870, and *Memoirs and Memoranda in Anatomy*, 1889.

THE PARIETAL BONES.

The parietals are two quadrilateral plates forming the middle region of the roof of the skull.

Borders. Their superior borders are straight and deeply dentated, united one with the other in the middle line by the *sagittal suture.* Their posterior borders, similarly dentated, form with the occipital the *lambdoidal suture.* The anterior borders, less deeply serrated, are united to the frontal bone by the *coronal suture,* and have the peculiarity that in the lower part the outer table overlaps the frontal bone, while in the upper the outer table of the frontal overlaps the parietals. The inferior border is in the greater part of its extent concave, with the inner table projecting as a sharp edge far beyond the outer, and separated from it by a fluted surface which rests against the squamous part of the temporal bone, and forms with it the *squamous suture.* Behind this a straight portion joins the squamous edge at a projecting angle, and is serrated to articulate with the mastoid portion of the temporal, forming with it the parieto-mastoid suture (*additamentum suturae squamosae*); while in front the anterior inferior angle articulates squamously with the great wing of the sphenoid. This articulation with the sphenoid (*pterion*) is, however, sometimes absent on one or both sides, and is variable in extent when present.

The **outer surface** has its greatest convexity, the parietal eminence, rather above and behind the middle. Sweeping upwards from behind, and arching forwards below the eminence, is the *temporal ridge,* dividing the superficial upper part from the temporal fossa, and showing more or less distinctly an upper and lower line with an interval between, the upper line marking the superficial limit of attachment of the temporal fascia, and the lower the margin of the temporal muscle. Near the middle line, and behind the eminence, there is usually an aperture for a vein—the *parietal foramen.*

The **deep surface** presents, along by the upper border, a depression which, when the right and left bone are fitted together, is completed into a mesial groove, marking the course of the superior longitudinal sinus, and in continuity with the superior groove of the occipital. Close to the posterior inferior angle there is a small curved portion of the groove for the lateral sinus. There are also three sets of hollows which are not peculiar to the parietal. The whole surface is covered with shallow *digital impressions* corresponding with the cerebral convolutions, and is traversed by sharp-bordered branching grooves, ramifying from the neighbourhood of the anterior inferior angle, and marking the course of the branches of the middle meningeal artery. Lastly, in adult skulls there are almost always seen, near the upper border, some irregular depressions caused by the growths called Pacchionian corpuscles eating into and pushing before them the vitreous table.

THE FRONTAL BONE.

The frontal bone forms the whole of the forehead, and also the roofs of the *orbits* or hollows for the eyeballs, and is divisible into frontal and orbital plates. It will be better understood if compared at the outset with the frontals of some other animals, such as the dog or the sheep, when it will be seen how the borders internal to the orbits have been, throughout the vertebrate series, anterior, while the roofs of the orbits are the lower parts of walls originally looking outwards; and that the peculiar form of the human frontal depends on the large development of the brain and the narrowness of the nose. In early childhood it consists, as in most adult vertebrates, apes and monkeys excepted, of a pair of bones united in the middle line by a *frontal suture;* and not unfrequently this suture persists in the serrated form throughout life.

Borders. The border forming with the parietals the *coronal suture* is serrated and overlaps them above, while on each side the parietal overlaps the frontal below; and below the level of the parietal the border expands into a triangular surface looking downwards to articulate with the great wing of the sphenoid. In front of this triangle is the serrated extremity of the *external angular process*, which articulates with the malar; while, internal to the triangle, the posterior border of the orbital plate articulates with the orbital wing of the sphenoid. Between these plates, the *ethmoidal incisura*, or *notch*, extends forwards to the base of the frontal plate; it presents a large outer and a smaller inner margin, formed respectively by the outer and inner tables of the skull. Between these margins there is on each side of the incisura a row of shallow depressions, the roofs of air-cells in the lateral mass of the ethmoid bone, and, crossing transversely between them, two grooves, completing with that bone the *internal orbital canals*, the anterior of which gives passage to the nasal nerves. The margin internal to the cells articulates with the cribriform plate of the ethmoid, while the margin outside articulates in greater part with the orbital plate of the same bone, except for a short space in front, where it comes in contact with the lachrymal. In front of the lachrymal edge is a serrated margin curving forwards and inwards to the middle line, and articulating in its outer part with the superior maxillary, and in its inner with the nasal bone. In the middle line, in front of the incisura, the rough *nasal spine* projects down, articulating in front with the nasals, and behind with the central plate of the ethmoid. On each side of this is the opening into the *frontal sinus*, an air-cavity of variable and late development extending upwards and outwards over the orbits, lined with mucous membrane prolonged from the nose, and most extensive in the adult male.

The surfaces of the frontal bone are the frontal, the orbital, and the cerebral. The most prominent part of the convexity of the frontal surface on each side is called the *frontal eminence;* and above the orbit is an arched elevation, the *superciliary ridge;* while between the two superciliary ridges

there is a median elevation over the nose, called the *glabella*. The inferior limit of the frontal surface between it and the orbit is called the *orbital arch*, and presents in its inner half the *supra-orbital notch*, sometimes converted into a foramen, and sometimes double, transmitting the supra-orbital nerve and artery. The inner extremity of the arch is sometimes called the *internal angular process*, while the outer end is the *external angular process*, a stout projection already mentioned as articulating with the malar. The outer margin of this process is formed by the *temporal ridge*, which passes upwards and backwards to be continued on the parietal bone, and separates the forehead from the temporal fossa. The orbital surfaces are triangular, their inner edges parallel, and their outer edges at right angles one to the other. Under cover of the external angular process lies a depression, *fovea lachrymalis*, in which is lodged the lachrymal gland; and beneath the inner end of the arch there is a small indented pit, *fovea trochlearis*, marking the position of the pulley of the tendon of the superior oblique muscle of the eyeball. The cerebral surface presents a continuous concavity, into the floor of which there project two convexities over the orbits, more dimpled by cerebral convolutions than the rest of the surface, and consisting opposite these dimples, as also posteriorly, of a single plate of bone without diploe. In the middle line, at the base of the frontal spine, is a groove completed by the crista galli of the ethmoid into a foramen (*f. caecum*), containing a minute vein opening into the commencement of the superior longitudinal sinus, and over this is the *frontal crest* broadening out into a mesial groove continuous above with that formed by the two parietals. Depressions caused by Pacchionian bodies may be seen on each side.

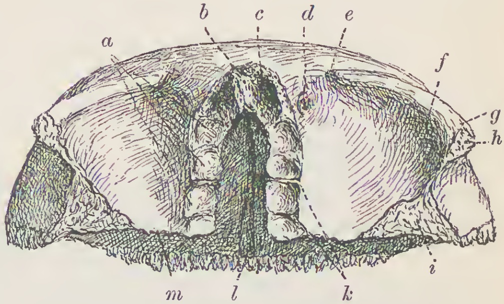


FIG. 199.—FRONTAL from below. *a*, Ethmoidal sinuses; *b*, nasal spine; *c*, frontal sinus; *d*, trochlear depression; *e*, supra-orbital notch; *f*, lachrymal fossa; *g*, external angular process; *h*, for malar; *i*, for sphenoid great wing; *k*, internal orbital canals; *l*, superior longitudinal sinus; *m*, for sphenoid small wing.

THE SPHENOID BONE.

The sphenoid bone, occupying the middle of the base of the skull and spreading outwards on the sides, articulates with all the other cranial bones, as also with the palatals, malars and vomer. Owing to the remarkable manner in which the human cranium is curved on itself to make room by extension of the roof for the great size of the cerebral hemispheres, the sphenoid is compressed from before backwards; but the ordinary mammalian arrangement is that the sphenoid consists of two

mesial bones, one in front of the other, each with a pair of wings spreading out in the cranial wall, and a pair of descending processes. Besides this, the parts called in human anatomy internal pterygoid processes remain in other animals separate throughout life as the pterygoid bones. Also, the parts called in man sphenoidal turbinated bones are in other animals absent altogether, being in fact elements intercalated between the lateral masses of the ethmoid and the vomer, bones always in other mammalia placed edge to edge, and usually early united to form one piece.

The human sphenoid is described as consisting of a body and three pairs of processes, viz., the *great alae* and the *orbital alae* (both taking part in the wall of the cranial cavity), and the *pterygoid processes*, projecting downwards, and consisting each of an external and an internal pterygoid plate. But in the child the constitution of the sphenoid is much better seen, and it can then be observed that inferiorly the fore part of the body is marked off by a transverse notch from the hinder part, and has a rounded outline filled with cancellated tissue; that the internal pterygoid plates, though adherent, are distinguishable in their whole original extent, and that a pair of hollow pyramids, the *sphenoidal turbinated bones*, lie on the sides of the fore part of the body, and have as yet no adhesion to the sphenoid.

Fig. 200.—Sphenoid at Birth, $\frac{2}{1}$, from below. *A*, Body and orbital wings; *B*, left great wing not yet united to body. *a*, Orbital wing pierced by optic foramen; *b*, place of union of postsphenoid and presphenoid; *c*, external pterygoid plate; *d*, internal pterygoid plate; *e*, foramen ovale and foramen spinosum not completed.

The body is indistinguishably united to the basilar process of the occipital after the twentieth year. Its upper surface slopes upwards from behind, forming along with the basilar process of the occipital a continuous plane, the *clivus*, which terminates in front in a thin plate, the *dorsum sellae*, forming the posterior limit of a deep depression, the *sella turcica, ephippium* or *pituitary fossa*, which is occupied by the pituitary body. In front of the pituitary fossa is the *olivary eminence*, a transversely oval surface separated from it by a line, and in front of the olivary eminence the level *orbital wings* meet in the middle line at a slightly higher level. The dorsum sellae is thick and irregular at its summit, and has projecting angles called *posterior clinoid processes*. The olivary eminence slopes at each side into a foramen directed forwards and outwards into the orbit, the *foramen opticum*; and on it rests the optic commissure, from which the optic nerve on each side passes out-

wards through the optic foramen, accompanied by the ophthalmic artery. The optic foramen pierces the base of the orbital wing, and, continuous with its upper border, a smooth process of that wing projects backwards, the *anterior clinoid process.* On each side three marks indicate the course

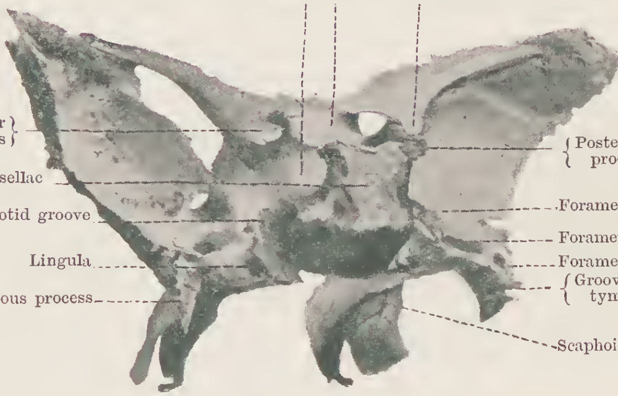


FIG. 201.—SPHENOID from behind.

of the internal carotid artery, viz., posteriorly, a deep notch separated from the posterior border of the great wing by a thin process, *the lingula*; secondly, a *carotid groove* running forwards at the side of the sella turcica; and thirdly, a concave margin internal to the anterior clinoid

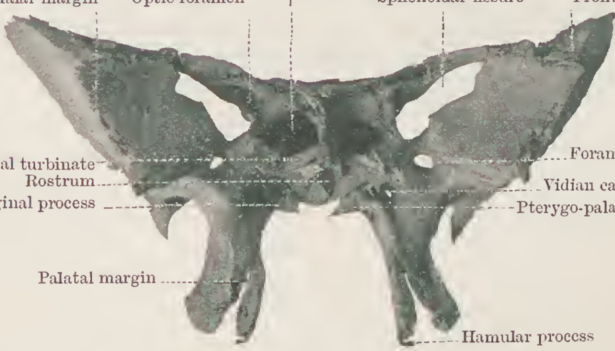


FIG. 202.—SPHENOID from the front.

process and behind the foramen opticum. A spicule, the *middle clinoid process*, may be present internal to the groove, and reach up to the anterior clinoid process. Inferiorly, opposite the posterior edges of the pterygoid process, there is a transverse groove made by a rough ledge looking backwards, the attachment of the posterior wall of the pharynx.

Further forwards, on each side, there is a projection inwards of the surface continuous with the internal pterygoid plate : it is called the *vaginal process*, and articulates edge to edge with the vomer, while it is partially covered in by the sphenoidal process of the palatal bone, and has on it a groove, completed anteriorly by the palatal into the *pterygo-palatine canal*, a small passage containing the pharyngeal branch of Meckel's ganglion. Extending from between the vaginal processes, the fore part of the body projects forwards as a narrowing mesial keel, *the rostrum*, covered by the vomer, and on each side is a triangular plate with its apex pointing backwards. This is the portion of the sphenoidal turbinated bones termed *triangular bone of Bertin*, and curves upwards in front so as to look forwards and wall-in the *sphenoidal sinus*, leaving an aperture by which the sinus opens into the upper and back part of the nasal fossa. Between the two sphenoidal sinuses the body is reduced to a thin *septum sphenoidale*; and in front this thin plate has to be broken separate from the central plate of the ethmoid, and is named *sphenoidal crest*.

The **sphenoidal turbinated bones** are, however, structures which reach the perfection of their development in childhood, and consist at that time of four distinct ossicles, of which the largest is the bone described by Bertin, while an upper and outer and an upper and inner plate complete in early years the walls of the sphenoidal sinuses, but become soon absorbed. The fourth ossicle is a constant orbital element, which may become adherent to either the sphenoid, the os planum of the ethmoid, or the orbital process of the palatal, or to all of these, and always completes with the palatal bone the *spheno-palatine foramen*.[1] On this account the sphenoidal turbinated bones sometimes are broken away with the sphenoid, sometimes with the ethmoid, and sometimes with the palatals, along with which last they were figured by the first Monro. In the lower animals, the sphenoidal turbinates being absent, the spheno-palatine foramen is completed by the ethmoid, and is ethmo-palatine.

Fig. 203.—The Vomer, Ethmoid, Sphenoidal Spongy Bones, and Left Palate and Maxillary Bones, from the Skull of an Infant. Seen from behind (slightly enlarged). *a*, Orbital plate of the ethmoid; *b*, posterior extremity of the vomer; *c*, sphenoidal process of the palate bone; *d*, orbital surface of the palate bone, and immediately above it is the orbital portion of the sphenoidal spongy bone. Between the two processes of the palate bone is the spheno-palatine foramen, completed above by the inferior portion of the sphenoidal spongy bone. *e*, The superior portion of the sphenoidal spongy bone.

The **orbital, anterior or small alae or wings** spread out horizontally from where they meet in the middle line in front of the body. At this point there is usually a slight projection forwards, *the ethmoidal spine*, and the whole anterior border is serrated, articulating in the middle with the ethmoid, and further out with the orbital plate of the frontal. The posterior border, smooth and free, separates the anterior from the middle fossa

[1] See Cleland on "Vomer, Ethmoid and Submaxillary Bones" (*Philosophical Transactions*, 1862).

of the base of the cranium, and slopes outwards and forwards to meet the anterior at a point which comes almost or quite into contact with the great wing. The orbital wing arises, not only internal to the optic foramen, but also external to it by a strong bar separating that foramen from the *sphenoidal fissure*; and in front of the exit of the optic foramen a short *internal orbital plate* separates the sphenoidal sinus from the orbit, and articulates in front with the os planum of the ethmoid and the orbital plate of the sphenoidal turbinated bone.

The great or posterior ala or wing arises from the body, opposite the side of the sella turcica, and rapidly expands backwards and forwards. It is separated from the small wing by the *foramen lacerum orbitale* or *sphenoidal fissure*, a gap rounded internally, and narrowing and ascending as it extends outwards,—the aperture of exit of the third, fourth and sixth nerves, and the ophthalmic or first division of the fifth, and giving entrance to the ophthalmic vein. The great ala may be most conveniently described as divisible by a line drawn outwards from the inner end of the sphenoidal fissure into a posterior horizontal part and an anterior ascending part.

The *horizontal part* of the great ala forms portion of the floor of the middle fossa of the base of the cranial cavity, lying on a lower level than the sella turcica, and supporting the middle lobe of the brain. Its outer border articulates roughly with the squamous part of the temporal bone, and its posterior border, directed backwards as well as outwards, forms a thin edge which is barely in contact with the petrous portion of the temporal, completing with it inferiorly a groove in which lies the Eustachian tube. Projecting downwards from the posterior and outer angle, there is a short and stout *spinous process*, giving attachment by its rough edge to fibres of the tensor palati, and presenting on its inner side a small groove (Lucas) for the chorda tympani nerve; and immediately in front of this is the *foramen spinosum*, through which the middle meningeal artery enters. Anterior and internal to the foramen spinosum, and, like it, closed off in development from the posterior border, is the large *foramen ovale* which transmits the inferior maxillary nerve, the third division of the fifth. Considerably further forwards and inwards, closed off originally from the anterior border, and lying outside and below the inner end of the sphenoidal fissure, is the *foramen rotundum*, which is directed forwards immediately below the level of the orbit, and transmits the superior maxillary or second division of the fifth nerve.

The *ascending part* of the great ala lies altogether in front of the junction with the body, and is a three-sided mass projecting upwards and outwards. Its summit is rough, articulating principally with the frontal bone, but coming in contact also with the parietal outside and behind the frontal articulation. By means of its posterior border it articulates with the squamous part of the temporal bone, in continuity with the horizontal part of the ala; and anteriorly it presents a thin border which articulates with the malar, while internally, by means of a free border, it bounds the sphenoidal

fissure. The posterior or cerebral surface is continuous with the upper surface of the horizontal part; and another surface, looking downwards in continuity with the under surface of the horizontal part, forms with it the roof of the *zygomatic fossa*, giving origin to the upper head of the external pterygoid muscle. The external surface, separated from the lower by a *temporo-zygomatic ridge*, gives attachment to the temporal muscle. The remaining surface, looking forwards and inwards, forms portion of the outer wall of the orbit, and is bounded below by a free border, which separates it from a part looking into the *spheno-maxillary fossa*, and is the upper border of the *spheno-maxillary fissure.*

The pterygoid process projects downwards and somewhat forwards. It consists of an external and an internal pterygoid plate, united in front for more than half their length, but separated below by a rough-edged *notch*, into which the pyramidal process of the palatal fits so as to fill it up. The space left between the two plates looks backwards, and is called the *pterygoid fossa.* The *external pterygoid plate* is slightly everted and broader than the internal, and gives attachment by its outer and inner surfaces respectively to the external and internal pterygoid muscles. From its border a spicule or band sometimes extends back to the spinous process, completing a foramen through which the outer branches of the inferior maxillary nerves may pass. The *internal pterygoid plate*, after being continued down as far as the external, has a slender prolongation carried downwards and outwards, the *hamular process*; and at the upper and inner part of the pterygoid fossa is a small depression, called *scaphoid fossa*, indicating the origin of the tensor or circumflexus palati muscle, whose tendon winds round the hamular process. The anterior surface of the pterygoid process expands above into an area reaching up to the orbital surface of the great wing, and forming the posterior wall of the spheno-maxillary fossa. In the upper part of this wall the front of the foramen rotundum is seen, and internal to this, and below it, the anterior opening of the *Vidian canal*, which, lying between the originally separate ossification of the internal pterygoid plate and the rest of the sphenoid, transmits the Vidian nerve and vessels, and passes backwards to reach the *foramen lacerum medium*, a ragged aperture left between the sphenoid, the petrous portion of the temporal and the basilar process of the occipital.

THE TEMPORAL BONE.

The temporal bone possesses considerable complexity, partly owing to its connection with the organ of hearing, and partly to its being composed of heterogeneous parts which happen to be united in the human subject by osseous substance. It is usually described as consisting of three parts, the *squamous*, the *mastoid* and the *petrous.* But of these the squamous is the only part which can claim to be a single distinct element in development and comparative anatomy; thus, the mastoid is at no period a completed structure separate from the petrous, and it is cus-

tomary to include along with the petrous both the styloid process and the tympanic plate, which are independent developments.

The petrous part contains within it the essential organ of hearing called the *labyrinth* or internal ear, which is divisible into portions called the *cochlea* and the *vestibule* and three *semicircular canals*, all receiving branches from the auditory nerve. The orifice of the ear, *external auditory meatus*, has the squamous part above it, the mastoid behind it, and the rough *external auditory process* of the tympanic plate below and in front of it. It leads

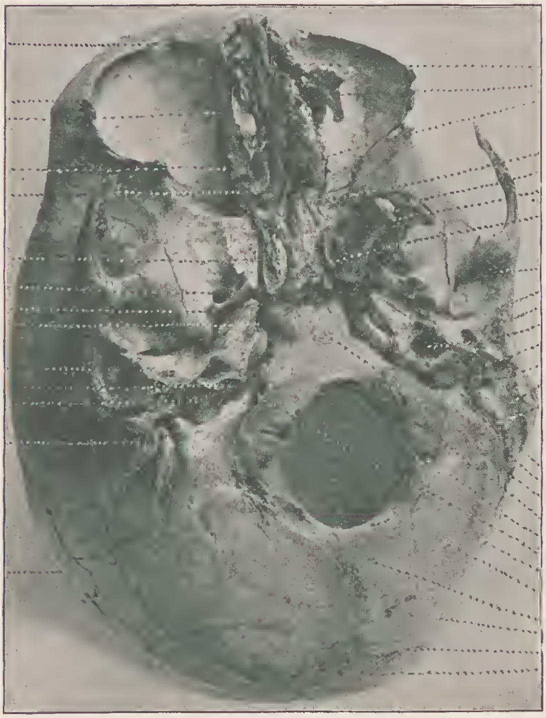


FIG. 204.—BASE OF SKULL, about ten years old, with face bones removed, as also right pterygoid process and right uncinate and inferior turbinated processes of ethmoid. The occipital is ununited to the sphenoid.

into the *tympanum* or middle ear, a chamber transversely narrow, but expanded from before backwards, which in the recent state is separated from the external ear by the membrana tympani, and communicates with the pharynx by means of the Eustachian tube. It may also be mentioned that the tympanum contains within it three ossicles, named *malleus*, *incus* and *stapes*, minute structures utilized in connection with hearing, but integrally connected with the mandibular skeleton, both in the mammalian embryo and in adult non-mammalian vertebrates.

The squamous part has an extensive free border, which may be traced forwards from where it forms the outer wall of a deep cleft in front of

the serrated upper border of the mastoid part: it arches upwards and forwards, forming with the parietal the *squamous suture*, and its outer table is prolonged considerably beyond the inner, as a thin scale with a fluted surface which looks inwards, so that the two parietals are grasped between the two temporals of opposite sides. In front of the parietal the free border articulates with the great wing of the sphenoid, and is directed downwards, and then obliquely backwards and inwards, becoming more distinctly serrated as it proceeds, till it ends by coming in contact with the anterior border of the petrous. From this point a fissure, the *fissure of Glaser*, passes outwards to the front of the external auditory meatus, and separates the quadrate surface for the temporo-maxillary articulation from the tympanic plate. *The articular surface*, in its hinder

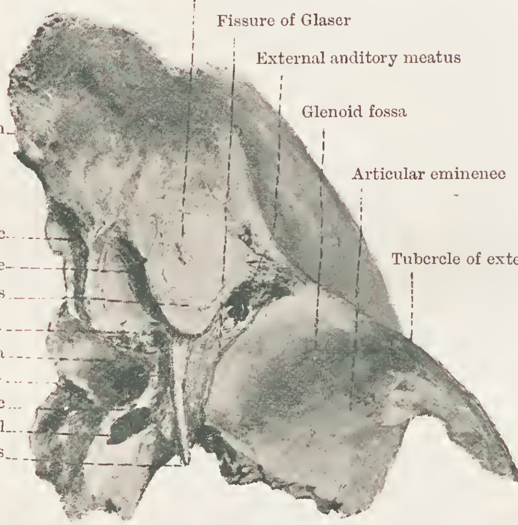


FIG. 205.—RIGHT TEMPORAL from below.

part, presents a hollow, elongated inwards and a little backwards, the *glenoid fossa*, in which the condyle of the lower jaw lies when the mouth is closed, and in front a convex eminence on which it rests when the mouth is opened: at the outer end of this eminence there is a tubercle marking the attachment of the external lateral ligament; and in front of the Glaserian fissure, a *postglenoid tubercle* separates the glenoid fossa from the external auditory meatus. The external and anterior part of the articular surface lies beneath the obliquely folded origin of an elongated bar, the *zygoma* or *zygomatic process*, which curves outwards and forwards to form with the malar bone the *zygomatic arch*. The lower border of the zygoma is rough, giving attachment to the masseter muscle, and is continuous with the eminence of the articular surface, sometimes spoken of as its *anterior root*; the upper border is narrower than the lower, and is

much longer, both because it is prolonged further forwards, and because it begins further back opposite the postglenoid tubercle. It is continued into the *posterior root* over the external auditory meatus, and still further back into a *supramastoid crest*, and, together with these, gives attachment to the temporal aponeurosis. Above and behind the external auditory meatus a little pit, the *post-auricular depression*, is almost constantly formed in connection with a slightly projecting squamous attachment of the cartilage of the ear. The external surface of the squamous part is marked by the attachment of the temporal muscle; the internal surface is marked by impressions of cerebral convolutions and branches of the middle meningeal artery.

The mastoid process has two serrated borders, a horizontal and a vertical, which articulate respectively with the parietal and occipital. It is named

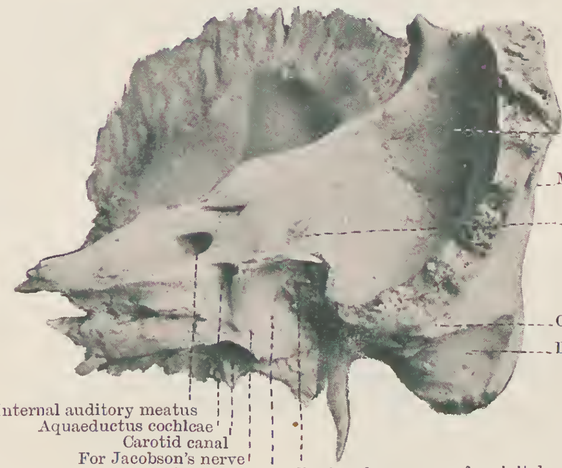


FIG. 206.—RIGHT TEMPORAL from behind.

from the *mastoid process*, which projects downwards behind the external auditory meatus and owes its inflated appearance in the adult to air-cells opening into the back of the tympanum. On the deep side of the mastoid process, overhung by it, is the deep *digastric fossa* or *cleft*, giving origin to the posterior belly of the digastric muscle; and from the extremity of the process a line passes upwards and backwards, dividing the muscular roughnesses into an anterior area, the origin of the sterno-mastoid muscle, and a posterior area, which is closer to the digastric groove, and subdivided into a part devoted to the splenius capitis, and a smaller and deeper part receiving the insertion of the trachelo-mastoid muscle. Internal to the digastric cleft, and close to the occipital border, is the *occipital groove*, which lodges the occipital artery. On the cerebral surface, in the retreating angle between the mastoid and the petrous parts, there descends a deep groove, in which lies the sigmoid part of the lateral sinus, and

usually a *mastoid foramen* is found conveying a vein from the outside into it, through the bone. A fissure in connection with the mastoid branch of the occipital artery, situated, in its most constant part, low on the mastoid process, though often figured has failed to be correctly appreciated. It is marked *arterial fissure* in Fig. 205.

The petrous part, so called from its hardness, is a three-sided pyramid directed inwards and forwards from its base at the external auditory meatus to its apex at the side of the basilar process of the occipital. Two surfaces, an upper and a posterior, look into the cranial cavity, and are separated by a long, prominent and free edge, which, extending to the apex from behind the cleft at the back of the squamous suture, divides the posterior from the middle fossa of the base of the skull, and is grooved by a venous channel, the superior petrosal sinus. The **posterior surface** presents nearer the apex than the base, the *internal auditory meatus*, a large and short canal directed transversely outwards, and transmitting the facial and auditory nerves and the auditory artery. Within the meatus is seen the *lamina cribrosa* blocking up its extremity, except at the upper and fore part, where is placed the inner aperture of the *aqueduct of Fallopius*, or canal of exit of the facial nerve, which, when followed through the bone, will be found passing outwards between and above the cochlea and vestibule, then turning backwards, separated from the tympanic cavity by a thin wall, and lastly, directed abruptly downwards to the stylo-mastoid foramen. The foramina of the lamina cribrosa are arranged in groups, the anterior conveying nerves and vessels of the cochlea, and the posterior and upper those of the vestibule. External to the internal auditory meatus is the *aquaeductus vestibuli*, an irregular fissure covered by a bony scale of late development; and, on the border between the posterior and inferior surfaces, directly below the internal auditory meatus, is another small opening similarly formed, called *aquaeductus cochleae*.

On the **superior surface** of the petrous part there is a distinct depression over the apex, marking the position of the Gasserian ganglion. Further out there is a groove leading into the aperture called *hiatus Fallopii*, directed outwards and backwards to open speedily into the aqueduct of Fallopius, and transmitting the great superficial petrosal nerve; more externally, an elevation from behind forwards marks the position of the superior semicircular canal; and still further out, a fissure is generally found extending backwards a variable distance, and indicating where the petrous part, after roofing the tympanum by means of a thin prolongation, called *tegmen tympani*, comes in contact with the squamous part.

The **inferior surface** of the petrous part of the temporal is divisible into two, one in front of the other; the posterior of these is really a border, continuous with the posterior border of the mastoid, and exhibits, from without inwards, (1) a recess to receive the jugular process of the occipital bone, (2) the *jugular fossa* in which the internal jugular vein lies as it passes through the foramen lacerum posticum between temporal and occipital

bones, (3) a depression bounding the inner or neural part of that foramen opposite the aquaeductus cochleae, already mentioned, and (4) a rough area articulating with the basilar process. The anterior or free division of the inferior surface presents in its outer half the *tympanic plate*; and this plate floors the external auditory meatus and the tympanic cavity; its anterior margin bounding the Glaserian fissure; its surface concave and smooth, separated by parotid gland from the temporo-maxillary articulation; and its posterior margin sheathing with a projecting edge, called *vaginal process*, the

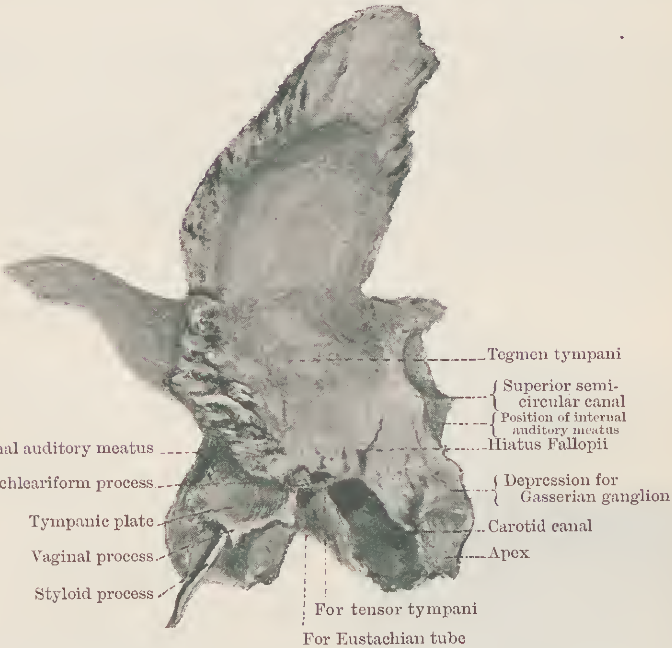


FIG. 207.—RIGHT TEMPORAL from before. The squamous portion and its zygomatic process are seen from the deep side. The mastoid process is seen behind the styloid process.

front of the *styloid process*, a cylindrical spike of variable length continued into the stylohyoid ligament. Close to the styloid process, and in front of the digastric cleft, is the *stylo-mastoid foramen* by which the facial nerve emerges from the aqueduct of Fallopius; and behind the inner end of the tympanic plate, internal to the jugular fossa, and in front of it, is the large round *carotid foramen*, the inferior aperture of the *carotid canal*, a canal which, entering vertically, is seen to turn at right angles within the bone and to run horizontally forwards and inwards to emerge at the apex into the foramen lacerum medium. The thin ridge between the carotid foramen and the jugular fossa presents a small foramen by which Jacobson's nerve enters to reach the tympanum. In front of the carotid foramen, at the inner end of the Glaserian fissure, is an irregular opening in the retreating angle between the petrous and squamous parts, the *Eustachian orifice*; and a closer

inspection shows it to be divided by a scoop-like lamina, the *cochleariform process*, into an upper part which transmits the tendon of the tensor tympani muscle, and a lower, which is the osseous part of the Eustachian tube. The tegmen tympani projects downwards outside the Eustachian orifice, and appears in the inner half of the Glaserian fissure, especially in young subjects; and the part of the fissure between the tegmen and tympanic plate is important as that through which the chorda tympani nerve passes, and in which the processus gracilis of the malleus is entangled.

The *foramen lacerum medium* is a gap in the base of the skull, best named thus, to distinguish it from the foramen lacerum posticum, and from the sphenoidal fissure which has sometimes been called foramen lacerum anticum. It is bounded in front by the inner part of the posterior border of the great wing of the sphenoid, internally by the basilar process of the occipital, and behind and externally by the apex of the petrous part of the temporal. No structure passes directly through it, but it is traversed by the internal carotid artery and the continuations backwards of the Vidian nerve.

THE ETHMOID BONE.

The ethmoid bone consists, fundamentally, of a mesial and a pair of lateral elements not united until after birth, and then only by means of a cribriform plate growing out from the mesial element. In animals other than man the mesial part is often united to the sphenoid long before it is connected with the lateral parts; and in mammals generally, the lateral parts are united by means of the vomer, long before they are joined by the cribriform plate.

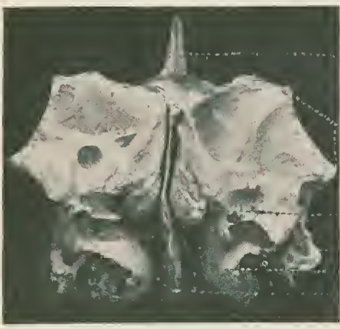


Fig. 208.—Ethmoid from behind.

The **mesial or central plate** (*mesethmoid*) forms the upper part of the septum separating the right and left nasal fossae, and grows from above downwards at the expense of the septal cartilage of the nose. In the greater part of its extent it is reduced to a thin lamina; but inferiorly its border is of the thickness of the septal cartilage, with which it is continuous, and in the hinder part of the extent of this border there is osseous continuity on one or both sides in the adult with the vomer. The posterior border is in osseous continuity with the sphenoidal crest, and the anterior border articulates with the nasal spine of the frontal and with the nasal bones. The upper border appears in the cranium above the

cribiform plate as a ridge rising in front into a thick process, the *crista galli,* to which the falx cerebri is attached; and the base of the crista galli is broadened out in front, and grooved to complete with the frontal bone the minute venous canal called foramen caecum.

The **cribriform plate,** extending outwards from the central plate, articulates with the frontal and fills up its incisura, while immediately below this it is united on each side with the lateral mass. The upper surface is depressed on each side, and lies beneath the olfactory bulbs; and the plate is called cribriform from being pierced by the filaments of the olfactory nerves. The larger and more numerous apertures have their walls prolonged a certain way on the central plate and lateral masses respectively, while those between are fewer and smaller, and are simple perforations.

The **lateral mass**[1] (*lateral ethmoid*) is exceedingly light, consisting of walls of air-cells, an orbital plate, two turbinate processes, and an uncinate process, all of them thin laminae. Above, it presents a row of cells more or less opened into by separation from the frontal, whose cerebral table articulates with the cribriform plate internal to the cells, while its superficial table articulates outside them with the orbital plate. The *orbital plate* or *os planum* is an oblong plate forming greater part of the inner wall of the orbit, and articulating above with the frontal, below with the superior maxillary and slightly with the palatal, behind with the orbital element of the sphenoidal turbinated bone, and in front with the lachrymal.

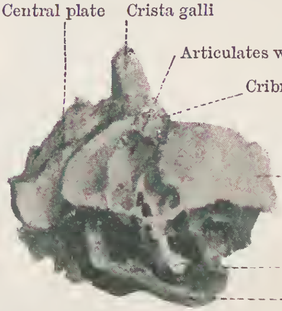


FIG. 209.—ETHMOID from front and left.

The air-cells are divided into *anterior, middle* and *posterior ethmoidal cells,* the anterior placed in front of the orbital plate, covered-in externally by the lachrymal bone, and opening into the middle meatus of the nose; the middle covered-in by the orbital plate, and opening into the middle meatus; the posterior covered-in by the orbital plate, but opening into the superior meatus of the nose. Descending from the anterior cells is the *uncinate process,* which turns backwards below the level of the orbital plate, taking part in the formation of the wall between the maxillary sinus and nasal cavity, and articulating with the upper edge of the inferior turbinated bone. The *turbinated processes* (Fig. 220) are two in number, distinguished as *superior* and *inferior* (or *superior* and *middle spongy bones),* and take part in the formation of the inner side of the lateral mass, which presents a continuous surface broken only in its posterior half, where it presents a cleft, the *superior meatus* of the nose, leading into the posterior ethmoidal cells. The upper margin of this meatus is formed by

[1] Prefrontal of non-mammalian vertebrates.

a lamina curved at its free edge, the superior turbinate process; and a similar but more curved lamina, the inferior turbinate process, not only forms the floor of the superior meatus, but extends forwards the whole length of the bone, its free edge descending as low as the uncinate process, and roofing the *middle meatus* of the nose. Between the uncinate process and the fore part of the inferior turbinate process, a passage, the *infundibulum*, passes up from the middle meatus, through the anterior ethmoidal cells, to open into the frontal sinus.

THE SUPERIOR MAXILLARY BONE.

The *maxilla, maxillary* or *superior maxillary* bone supports the teeth of the upper jaw in sockets or *alveoli*, sunk in a projecting ridge, which com-

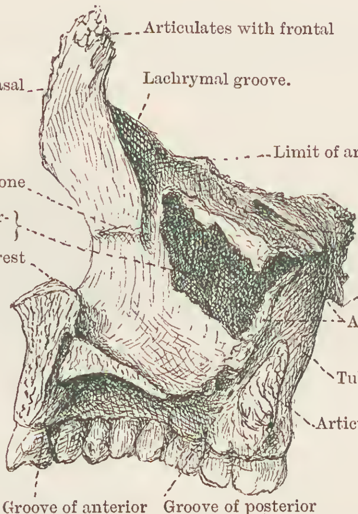


FIG. 210.—RIGHT MAXILLARY, internal and posterior view.

pletes an arch with its fellow, and is called the *alveolar process* or *dental margin*. Within this arch the palate plate extends backwards, and more externally the bulk of the bone rises up, presenting a facial, a zygomatic, an orbital and a nasal surface; while it sends a *frontal* (or *nasal*) process upwards to the cranium, and a *malar process* outwards.

The **palate plate** falls considerably short of the hinder end of the dental margin, and articulates behind with the palatal bone. It is vaulted and rough inferiorly, and on its upper or nasal surface is smooth, and thrown into a longitudinal furrow by the rising up of the mesial border, which is vertically fluted where it unites with its fellow, and in the hinder part of its extent makes with it a mesial ridge articulating with the keel of the vomer. But in front, above the dental margin, the mesial border is expanded upwards, and is separated from the part behind by an interruption which, in

the disarticulated bone, is inferiorly an open groove ascending from the palate, and superiorly is converted into a lateral foramen by projection of a thin lamina backwards. The open groove completes, with its fellow of the opposite side, the *incisor foramen* or *anterior palatine canal* of human anatomy, and the lateral foramina leading up from it are called foramina of Stenson; but a fissure passing out transversely, sometimes seen in the adult, and always in the young bone, indicates that the parts in front correspond with the intermaxillary bones of the lower animals, and that the foramina of Stenson correspond with the incisor foramina largely developed in many mammals, and inclosing in some a communication between the mucous membranes of the mouth and nose. The laminae which separate them are the mesial palatine processes of the intermaxillaries. Most frequently, especially in young subjects, two small apertures, *foramina of Scarpa*, for the naso-palatine nerves, are left in the mesial suture, so as to give four small foramina inclosed within the mesial incisor foramen; but this arrangement is not constant. The upper edges of the heightened parts of the mesial borders unite to form the *nasal* or *intermaxillary crest*, grooved for the front of the vomer and for the septal cartilage of the nose, and projecting forwards as the *nasal spine*.

Fig. 211.—Palate of Skull of Child about Six Years Old. *a*, Anterior palatine canal with its four foramina, viz., Scarpa's in the middle line, and Stenson's at the sides; the line of suture between maxillary and intermaxillary passes outwards below *a*; *b*, posterior palatine canal; *c*, tuberosity of palatal; *d*, external pterygoid plate; *e*, hamular process; *f*, one of the foramina behind the incisor and canine teeth of children, leading to the sacs of the permanent teeth.

The **facial surface** reaches the middle line below, and presents, higher up, an excavation of the inner border, the *nasal incisura.* Still further up, it is continued on the frontal process, up to the frontal bone, and articulates internally with the nasal bone, while externally it is separated by a smooth border from the inner wall and floor of the orbit. Externally the orbital border is limited by the *malar process*, a stout projection with a ragged triangular surface looking upwards and outwards to articulate with the malar bone, and with an overhanging smooth border below, beneath which the facial is continuous with the zygomatic surface. Eminences are seen corresponding with the roots of the teeth, and especially the canine fang causes a prominence which separates a slight *myrtiform* or *superior incisor fossa* from a larger depression external to it, namely, the *canine fossa*, from which the levator anguli oris and compressor naris muscles take origin. Above the canine fossa is the *infra-orbital foramen*, from which the infra-orbital nerve and artery emerge; and above the foramen the levator labii superioris muscle arises.

The **zygomatic surface**, behind the malar process, is continued round to form the *tuberosity* which looks backwards, forming the anterior wall of the zygomatic and spheno-maxillary fossae, and is pierced by some minute apertures of *posterior dental canals* for nerves to the molar teeth. Superiorly this surface is separated from the orbital by a free margin, which forms the anterior border of the spheno-maxillary fissure, and is interrupted by the *infra-orbital groove.*

The **orbital surface** forms the whole floor of the orbit with the exception of a minute angle behind, which is completed by the palatal. The infra-orbital groove extends forwards in it, and its edges meet to form the *infra-orbital canal*, which terminates at the infra-orbital foramen. It gives off minute *middle* and *anterior dental canals*, conveying the nerves to the bicuspid and incisor teeth. The orbital floor is triangular, its anterior and posterior free margins being separated by the articular surface of the malar process; its inner margin, followed from behind forwards, articulates with the orbital process of the palate bone, the os planum of the ethmoid, and the lachrymal. Opposite the fore part of the latter it aids in bounding the entrance into the *nasal duct*, and in front is continued up into the *frontal process*, which forms the fore part of the inner wall of the orbit, and is grooved posteriorly to complete with the lachrymal bone the *groove for the lachrymal sac.*

The **nasal surface** is surmounted in front by the inner aspect of the frontal process, which articulates behind with the lachrymal bone, and completes with it some of the anterior ethmoidal cells. Lower down there is a projecting line directed backwards and upwards, the *crest for the inferior turbinated bone*; and behind this the *lachrymal groove* descends from the floor of the orbit and posterior wall of the nasal process, forming the greater part of the wall of the nasal duct, which is completed by the lachrymal and inferior turbinated bones. Behind this groove is a large opening leading into a cavity extending underneath the orbit forward to the facial wall, and back to the tuberosity, and in old subjects projecting even into the malar process. This is named the *maxillary sinus* or *antrum* of *Highmore.* The entrance into the antrum is greatly diminished by other bones, the inferior turbinated articulating edge to edge with the lower margin of the opening, and being met by the uncinate process of the ethmoid, while the palate bone overlaps from behind. Only the gap left in front of the uncinate process is constant, and in the recent state forms the communication between the antrum and the middle meatus of the nose. Above the opening of the antrum, close to the orbital margin, shallow depressions complete some of the middle ethmoidal cells; and the surface behind it, and as far forwards below as the posterior edge of the palate plate, is rough for articulation with the palate bone. The roughness is interrupted by a groove passing from inside the tuberosity, downwards and forwards, to complete with the palate bone the *posterior palatine canal*, and transmit the posterior palatine vessels and nerve, which may also groove the palate as they pass forwards.

After loss of a tooth the walls of its socket become absorbed, and when all have been lost, the whole dental margin disappears, and even further absorption takes place, greatly diminishing the size of the hard palate and making it flat.

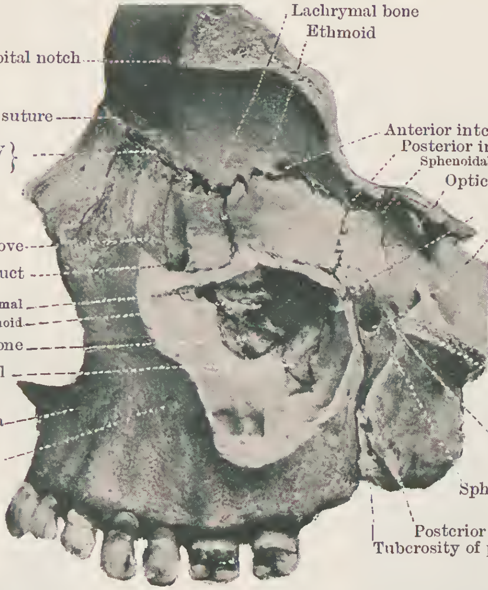


FIG. 212.—VERTICAL SECTION OF LEFT SIDE OF FACE, passing through orbit and maxillary sinus. (The orbital plate of the sphenoidal turbinated is very unusually large.)

THE PALATAL BONE.

The palatal or palate bone consists of a horizontal or palate plate, a vertical plate, and a thick pyramidal process projecting backwards and outwards from the back of the line of junction between the two plates.

The **palate plate** lies altogether internal to the dental arch of the maxilla; it articulates in front with the palate plate of that bone, and, in the same manner as that plate, it articulates with its fellow of the opposite side and comes in contact with the vomer; while, behind, it has a free concave margin giving attachment to the tensor palati, and forms with its fellow a mesial projection, the *palatal spine*, from which springs the azygos uvuli.

The **pyramidal process** or tuberosity has two triangular free surfaces—one continued backwards and outwards from the palate, and the other, with its base separated from the first by a free margin, and looking backwards to fill the gap between the pterygoid plates and so complete the pterygoid fossa. On the sides of this surface are rough borders for articulation with the pterygoid plates, and the outer of these is limited in front by a projecting line, sometimes scarcely apparent, but sufficient to prevent the external pterygoid plate from coming in contact with the maxilla below the spheno-maxillary fossa.

The **ascending plate** becomes very thin as it ascends, and is surmounted by two processes, the *orbital* in front and the *sphenoidal* behind, separated by the *spheno-palatine notch.* Its smooth internal surface is traversed by a projecting crest, higher in front than behind, for articulation with the inferior turbinated bone. The outer surface, mostly rough for articulations, is divided longitudinally by a smooth portion, broadest above where it begins on the posterior part of the orbital process and the base of the sphenoidal process, and narrowing below to a deep groove sloping forwards which goes to form with the corresponding groove on the maxilla the *posterior palatine canal*, while the upper part is the inner wall of the spheno-maxillary fossa. In front of this smooth part the outer surface

FIG. 213.—RIGHT PALATAL BONE. *A*, from outer side. *B*, from behind. *a*, Pterygo-palatine groove of sphenoidal process; *b*, orbital surface of orbital process; *c*, deep wall of spheno-maxillary fossa, with spheno-palatine notch above, and groove for posterior palatine canal below; *d*, crest articulating with inferior turbinated bone; *e*, palate plate; *f*, triangular surface of tuberosity which completes the pterygoid fossa; *g*, articulates with internal pterygoid plate; *h*, articulates with maxillary; *i*, articulates with external pterygoid plate; *k*, articulates with maxillary.

articulates with the maxilla, and also takes part in diminishing the entrance into the antrum; behind, it articulates below with the maxilla, and inclines backwards above to articulate with the internal pterygoid plate. The *orbital process* has two free surfaces—one, orbital, completing the orbital floor, the other, looking back into the spheno-maxillary fossa. It articulates in front with the maxilla, and internally with the ethmoid and orbital portion of the sphenoidal turbinated, and is hollowed in connection with middle ethmoidal cells. The *sphenoidal process* is a lamina directed upwards to the sphenoidal turbinated bone, and bending inwards and backwards below the curved origin of the internal pterygoid plate, grooved above to complete with the groove on that plate the *pterygo-palatine canal*, and articulating in front of it with the vomer. The *spheno-palatine foramen*

is the notch of the same name completed into a foramen by the sphenoidal turbinated bone; it is the ethmo-palatine foramen of other animals, and forms the communication between the spheno-maxillary fossa and the posterior nares, giving passage to branches of Meckel's ganglion and of the internal maxillary artery.

THE VOMER.

The vomer is a mesial bone entering into the formation of the septum between the nasal fossae. It is liable to lose much of its characteristic appearance before adult life is reached, partly by anchylosis with the central plate of the ethmoid, partly by absorption, and ought therefore to be first studied in the child. It consists of two alae united below and a mesial body descending from their line of junction.

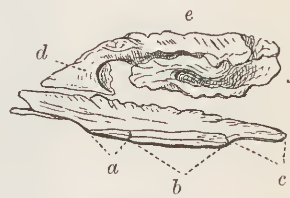


FIG. 214.—VOMER, ETC., OF CHILD. *a*, *b*, *c*, The parts of the inferior margin of the vomer for articulation with the palatal, maxillary, and intermaxillary bones respectively; *d*, sphenoidal turbinated bone; *e*, orbital plate of the ethmoid seen in perspective; *f*, inferior turbinated process of the ethmoid.

The **alae** are thick and expanded behind, fitting on under the sphenoid; and at their tips articulate edge to edge with its vaginal processes, and, in front of them, with the sphenoidal processes of the palate bones. In front of this their edges descend as they pass forwards, and remain in contact with the septal cartilage of the nose, which occupies the interval between them. Anteriorly they terminate in a grooved *intermaxillary process* which rests on the intermaxillary crest.

The **body** or keel is more and more elongated from above downwards as adult age is approached. Its posterior free margin descends from beneath the bifid posterior extremity of the alae to the back of the hard palate, and its inferior border extends forwards from this to fit in front behind the intermaxillary crest. In the young child it presents a flat expansion resting on the hard palate, with a mesial ridge and a transverse mark corresponding with the lines of junction of the bones beneath; and remains of this expansion may be sometimes detected in the adult turned down over the ridge which has risen below them.[1] A groove on each side below the line of origin of the alae indicates the course of the naso-palatine nerve.

In the adult, either one or both alae are united in osseous continuity with the central plate of the ethmoid. When the union has taken place on both sides, the septum of the nose is straight and a bar of cartilage is imprisoned between the two alae and the lower edge of the mesethmoid.

[1] Very occasionally a separate little spicule extends down into the suture between the maxillae from the point which fits in behind the intermaxillary crest. It nearly corresponds with the snout bone in ornithorhynchus and the boar. When I showed a specimen of it to Professor Goodsir, he recognized it as having been brought under his notice by the anatomical attendant.

But more frequently, especially in civilized nations, osseous union has occurred on only one side; the other ala undergoes absorption to a considerable extent, and the septum is bulged to the side on which the cartilage is left free, so as to narrow the corresponding nasal fossa, more frequently the left than the right, and restrict the space for the passing of both air and surgical instruments.

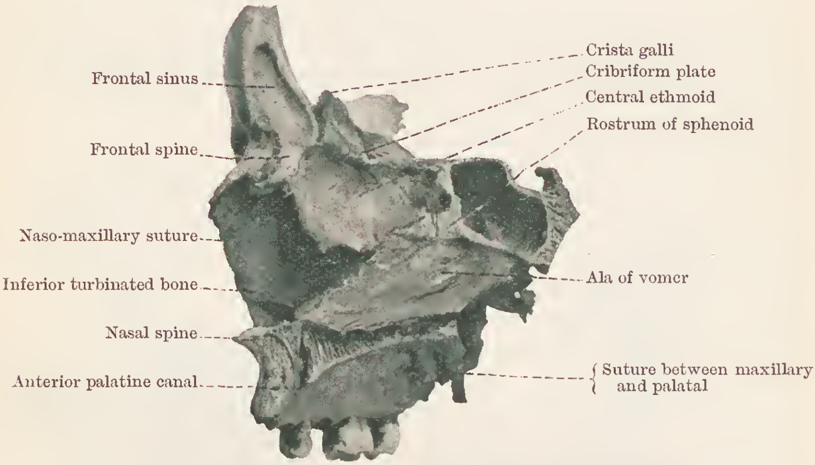


FIG. 215.—VERTICAL SECTION DISPLAYING SEPTUM NASI. (The mesial intermaxillary surface happens to be marked by two deep grooves, but the crest passes further back, and is already united to the maxillary behind Stenson's foramen.)

THE MALAR BONE.

The malar, jugal or cheek bone articulates broadly with the maxilla, and projects upwards and outwards, dividing into a stout and long frontal process articulating at its extremity with the external angular process of the frontal bone, and a compressed and shorter zygomatic process passing back to articulate with the zygomatic process of the temporal bone by a suture, the lower end of which projects further back than the upper.

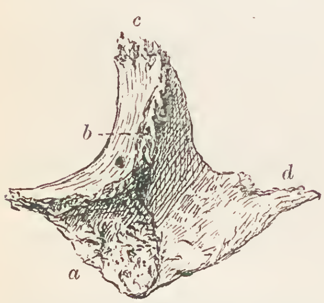


FIG. 216.—RIGHT MALAR, deep view. It articulates at *a*, with the maxillary; at *b*, with great wing of sphenoid; at *c*, with the frontal; at *d*, with zygomatic process of temporal.

Looked at from the front, the malar bone presents a surface bounded by two short borders converging to an inferior angle, and two longer borders converging above. The more internal of the two shorter borders is the anterior edge of the articulation with the maxilla; the more external is thick and uneven, extending back to the zygomatic process of the temporal, and giving attachment to the masseter muscle. The anterior and more internal of the upper borders is concave throughout, and extends

downwards and forwards, forming the outer and part of the lower border of the orbit; while the posterior and more external extends between the frontal and zygomatic processes, and has a double curve, convex above, concave below, and gives attachment to the temporal fascia.

Looked at on the deep side, it presents three surfaces, separated by ridges; namely, a surface continued from the inner side of the zygomatic process, longitudinally hollowed so as to complete the temporal and zygomatic fossae, and extending as far forwards as a line from the inferior angle to the tip of the frontal process; secondly, an orbital surface extending back from the orbital margin; and thirdly, a jagged triangular surface for articulation with the maxilla, intervening between the two others below, and sometimes continuous with an articular margin between them for the sphenoid, but more frequently separated from it by a very short free edge completing the anterior boundary of the spheno-maxillary fissure. The articulation with the sphenoid separates the orbit from the temporal fossa, and is continuous with the stout serrated articular surface for the frontal bone.

The *malar canal*, a small passage for the malar branch of the superior maxillary nerve, begins on the orbital surface and ends on the superficial surface, a little above its greatest prominence or *tuberosity*. Another aperture, the *temporal canal*, pierces the orbital plate higher up and gives passage to the temporal twig of the superior maxillary nerve.

The occurrence of a suture dividing the upper and inner part of the malar from the lower and outer is rarely met with in European skulls, but, in the Japanese, has been seen with unusual frequency, extending from the maxillary margin, sometimes upwards to the orbital, sometimes backwards to the upper margin of the zygomatic process.

THE LACHRYMAL BONE.

The lachrymal bone (os unguis) is a delicate scale on the inner side of the orbit, in front of the os planum of the ethmoid. It is grooved in its fore part to complete with the nasal process of the maxilla the depression which lodges the lachrymal sac, and articulates above with the frontal, and below with the orbital plate of the maxilla, while from its grooved part a *lower process* is prolonged into the canal for the nasal duct, and reaches down to the inferior turbinated bone. The groove is limited behind by a *crest* which at its lower end is sometimes more or less prolonged round the entrance of the canal for the nasal duct in the form of a *hamular process*. The lachrymal bone is often deficient or cribriform. In many mammals it is a more important bone, coming forwards on the face.

THE INFERIOR TURBINATED BONE.

The inferior turbinated bone separates the middle from the inferior meatus of the nose. It curves inwards and downwards from its attachments,

and has a free border running its whole length. Its attached border, in its fore part, is sloped upwards and backwards, articulating with the line on the maxilla, and behind this it reaches its highest point, articulating with the lachrymal and completing the lower orifice of the canal for the nasal duct. From this point a line of slope descends more gradually to the hinder end; in the first part of this slope the margin is folded over to look directly downwards and articulate edge to edge with the lower boundary of the aperture of the maxilla leading into the antrum; in the hinder part it articulates with the line on the palate bone. From the folded part bounding the antrum a small process projects upwards and articulates with the uncinate process of the ethmoid.

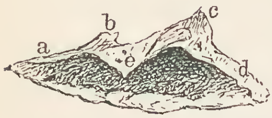


Fig. 217.—The Right Inferior Turbinated Bone, from lateral side. It articulates at *a*, with crest of palatal; at *b*, with unciform process of ethmoid; at *c*, with lachrymal; at *d*, with crest on maxillary; at *e*, with antral wall of maxillary.

THE NASAL BONE.

The nasal bone is thickest above, where it articulates by serrated suture with the frontal; the mesial border diminishes in breadth as it descends; the outer border is longer, and is narrow throughout to articulate with the nasal process of the maxilla. These three borders are serrated, while the inferior border is a thin irregular margin separated by fibrous tissue from the cartilage below. The deep side is marked in its whole length by a groove in which lies the nasal nerve.

THE MANDIBLE.

The *mandible, inferior maxillary bone* or *lower jaw* consists of right and left parts, which become united into one bone in the first or second year after birth; and the plane of union, even after it ceases to be indicated save by a mere line on the surface, is called the *symphysis*. The part beneath the upper jaw is called the *body*; from this a *ramus* ascends on each side; and the projection where the thick and strong lower border of the body passes into the hinder border of the ramus is called the *angle*. The hinder border of the ramus is continued up to the articular *condyle*, and the anterior border, rather concave below and convex above, and more nearly vertical than the posterior, terminates in the flat and pointed *coronoid process* which is separated from the condyle by a concavity, the *sigmoid notch*. The teeth are arranged in sockets whose walls form, like those of the upper jaw, a continuous *alveolar ridge* or *process*.

Superficially, at the chin is the *mental protuberance*, an ornament found only in man, and especially in the higher races. Above this, to the side of the symphysis, is a shallow *incisor fossa*, which gives origin to the levator menti. More externally is situated the *mental foramen*, the outlet of the *dental canal*, giving exit to the mental artery and

nerve; and passing beneath this foramen is the *external oblique line*, a distinguishable bar extending from the anterior border of the ramus to the mental protuberance. The whole surface of the ramus, including the coronoid process, gives attachment to the masseter muscle; and it is marked by it most strongly in its lower part, which, with the lower border in front of the angle, is ridged and prominent where the tendinous parts of the insertion are attached.

The deep surface presents, near the symphysis, inside the lower border, a rough depression to which the anterior belly of the digastric muscle is attached; and close to the symphysis, higher up, are two little spines, one immediately above the other, the lower giving origin to the

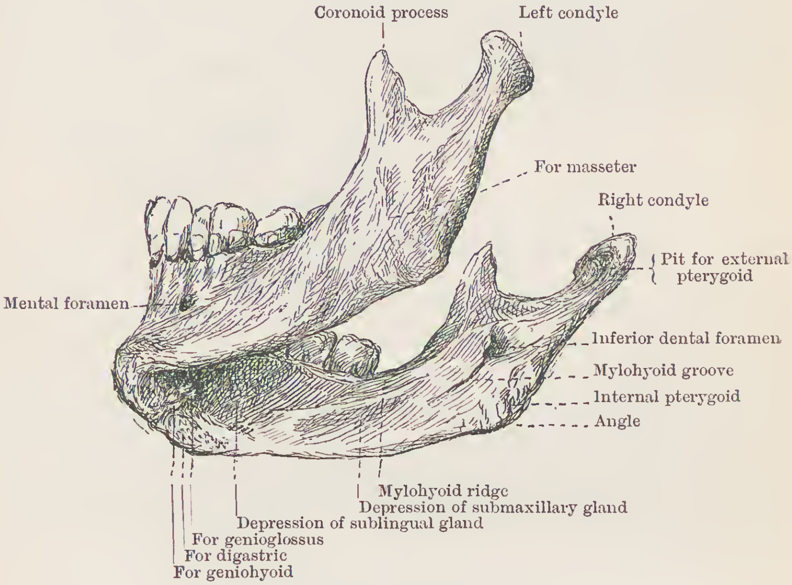


FIG. 218.—LOWER JAW, from left side and below.

geniohyoid muscle, and the upper to the genioglossus. From below these spines the prominent *internal oblique line* or *mylohyoid ridge* passes obliquely backwards and upwards, giving origin for some distance back to the mylohyoid muscle, and at its back part to some fibres of the superior constrictor of the pharynx, while it separates the depression for the sublingual gland above and in front of it from that for the submaxillary gland below and behind it. About the middle of the ramus is the *inferior dental foramen* leading into the dental canal and lodging the inferior dental nerve and vessels. Its inner margin is sharp with an upward projection, the *lingula*, giving attachment to the internal lateral ligament; and behind this is the commencement of the *mylohyoid groove* for the mylohyoid branches of the inferior dental nerve and vessels. On the inner side of the angle, and above it, there is a strongly marked

range of tubercles where the internal pterygoid muscle is inserted. The deep side of the coronoid process is smooth, giving attachment to the deep fleshy fibres of the temporal muscle; but its margins are sharp, receiving the fibrous part of the insertion of the same muscle, which in front is continued down to a rough depression from which the posterior fibres of the buccinator arise.

The **condyle** is supported on a constricted *neck*, on the front of which is a depression which receives the greater part of the insertion of the external pterygoid muscle. It is convex, and elongated from without inwards and backwards, its long axis pointing to the middle of the anterior margin of the foramen magnum.

At birth the ramus rises very slightly above the level of the body, and the angle is exceedingly obtuse. When, in consequence of loss of the teeth, the alveolar process is absorbed, the arch inclosed by the

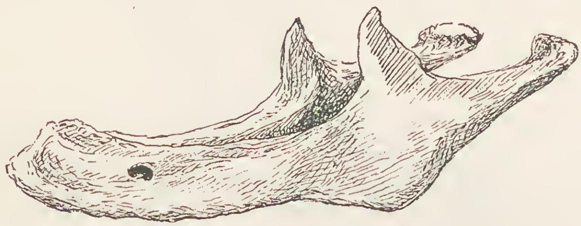


FIG. 219.—EDENTULOUS LOWER JAW OF OLD AGE.

lower jaw is increased in size; and as loss of the upper teeth diminishes the size of the palate, the lower jaw may, in edentulous old age, pass over the palate and approach the nose. But absorption is not confined to the alveolar part; it extends to the muscular surfaces; the angle becomes more and more obtuse, and the ramus shorter, reverting to the infantile form.

THE HYOID BONE.

The hyoid bone, though not accounted in human anatomy as part of the skull, is nevertheless related to it in development, remains closely connected with it in many mammals, and belongs to cephalic, not to cervical, segments of the organism. It consists of a body and two pairs of cornua, which sometimes, especially the smaller pair, remain separate from the body. The *body* is elongated transversely, and compressed so as to lie in an oblique plane from above downwards and forwards; superficially, it is marked by two superior impressions which give attachment to muscles of the tongue, and two inferior depressions which receive muscles from below. The *great cornua* project backwards from the extremities of the body, and are rounded at the tips where the lateral thyrohyoid ligaments are attached. The *small cornua*, short and pointed, are connected with the tips of the styloid processes of the temporal bones by slender bands, the *stylohyoid ligaments* (Fig. 222).

SUTURAL BONES.

Additional bones are of frequent occurrence in the sutures of the cranium, where they are called *Wormian bones* or *ossa triquetra.* They are most frequent in the lambdoidal suture, where a whole chain of them may occur even to the extent of separating the occipital and parietal completely, an arrangement which occurs both in this and other sutures in chronic hydrocephalus. Sometimes one, three or more large bones are developed at the expense of the upper part of the occipital. Wormian bones also occur in the sagittal, coronal, parieto-mastoid and even the squamous suture; and a single bone of the sort is common between the parietal and great wing of the sphenoid, and by becoming united with either frontal or squamous may give the appearance of these bones coming into contact (Schlocker). Small ossicles of the same description are said to occur in the face; as, at the outer end of the spheno-maxillary fissure, and in connection with the lachrymal bone.

FOSSAE OF THE SKULL.

Certain fossae of the skull require further description than could be given with that of the individual bones.

The temporal fossa is the part bounded above by the temporal ridge, in front by the malar and external angular process of the frontal, behind by the origin of the zygomatic process of the temporal, and below by the temporo-zygomatic ridge of the sphenoid; and it is arched across by the zygomatic arch and occupied by the temporal muscle.

The zygomatic fossa is separated from the temporal by the temporo-zygomatic ridge; it is roofed by the great wing of the sphenoid, and bounded internally by the external pterygoid plate. In front of it is the tuberosity of the maxilla, separated from the external pterygoid plate by a thin edge of the palate bone below, and by the *pterygo-maxillary fissure* higher up, and from the great wing of the sphenoid by the outer half of the *spheno-maxillary fissure.*

The spheno-maxillary fossa is the narrow space between the pterygoid process and the tuberosity of the maxilla, separated from the nasal fossa by the palate bone and communicating externally with the zygomatic fossa by the pterygo-maxillary fissure, and superiorly with the orbit by the inner half of the spheno-maxillary fissure. Into it open five foramina, viz., posteriorly, the foramen rotundum and the anterior extremities of the Vidian and pterygo-palatine canals; internally, the spheno-palatine foramen, and inferiorly, the posterior palatine canal.

The pterygoid fossa is the interval between the pterygoid plates; it looks backwards, its anterior wall is completed below by the palate bone, and in its upper and inner part is the scaphoid fossa. It is occupied by the internal pterygoid and tensor palati muscles.

The nasal fossa is opened into in front and behind by the anterior and posterior nares, is roofed by the nasal bone and the cribriform plate of the ethmoid, floored by the palate plates of the maxilla and palate bone, and separated from its fellow by the osseous septum of the nose formed by the vomer and central plate of the ethmoid. The external wall has its foremost part formed by the nasal and maxillary bones, and its hindermost part by the internal pterygoid plate, and in its intermediate extent is complicated by the projection inwards of turbinated bones which roof three galleries called *meatuses*. Of these the *inferior meatus* is the longest; it is roofed by the inferior turbinated bone and walled by maxilla and palate bone, and near its fore part has the nasal duct entering

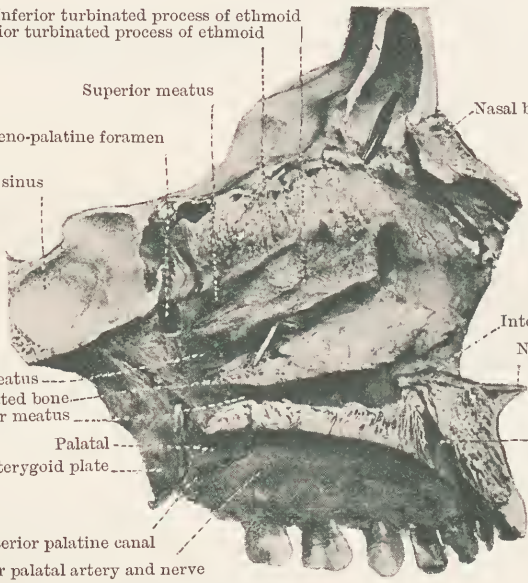


Fig. 220.—Left Nasal Fossa. (Pterygoid process pulled slightly from palatal.) A feather is passed from the frontal sinus to the middle meatus through the infundibulum.

it from above. The *middle meatus* is neither prolonged so far forwards nor so far back as the inferior; it is roofed by the inferior turbinated process of the ethmoid, and has, in the wall between it and the antrum, the uncinate process of the ethmoid and parts of the maxilla, lachrymal, and palate bone. The antrum opens into it directly, while the infundibulum leading up to the frontal sinus opens into the front part of its roof, with which the anterior and middle ethmoidal cells also communicate. The *superior meatus* between the superior and inferior turbinated processes of the ethmoid is much shorter than the middle meatus, and leads into the posterior ethmoidal cells. Behind it in the outer wall is the spheno-palatine foramen; and looking forwards towards it, above the posterior nares, is an opening into the sphenoidal sinus.

The orbit is of the form of a four-sided pyramid. Its entrance is bounded by the frontal, maxillary and malar bones. Its outer wall is at right angles to that of its neighbour, and is formed by the malar and the great wing of the sphenoid. The roof is formed in greater part by the frontal, but completed behind by the small wing of the sphenoid. Into the construction of the inner wall there enter the nasal process of the maxillary, the lachrymal, the os planum of the ethmoid, and the sphenoid, including the orbital element of the sphenoidal turbinated bone. The floor is formed mostly by the maxillary, and completed behind by

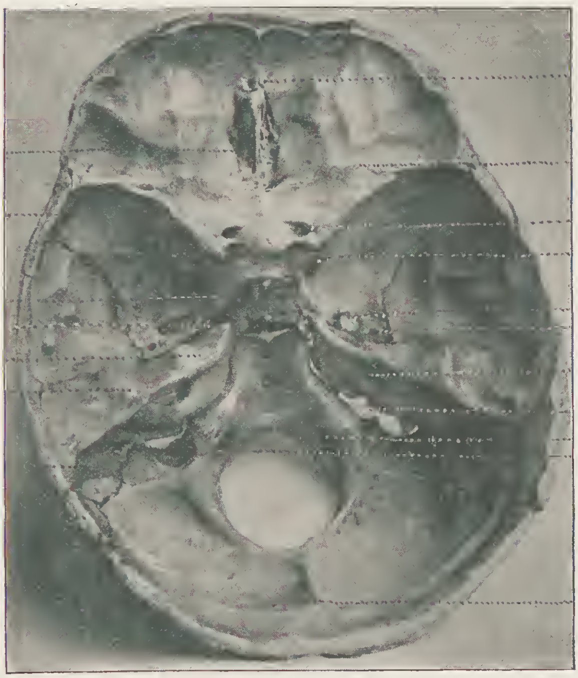


FIG. 221.—BASE OF CRANIAL CAVITY OF A CHILD, showing its anterior, middle and posterior fossae. Basilar process of occipital separated by a gap from the sphenoid.

the orbital surface of the palate bone, which always lies below the orbital element of the sphenoidal turbinated, and is often united to it by bony union. At the deep end, occupying the apex of the pyramidal cavity of the orbit, is placed the optic foramen; and below, and to the outside of this, is the wide inner end of the sphenoidal fissure, while the outer end of that fissure is prolonged in the angle between the roof and the outer surface. The spheno-maxillary fissure lies in the angle between the outer wall and the floor, in its posterior two-thirds or more. In the inner wall are the anterior and posterior internal orbital foramina, between ethmoid and frontal bone; and near the front is the lachrymal groove formed by the lachrymal and the nasal process of the maxilla, and

leading down into the nasal duct. The foramina in connection with the floor are two, the nasal duct and the commencement of the infra-orbital canal.

The three fossae basis cranii correspond with the three main levels of the floor of the interior of the cranium. The *anterior* is formed by the orbital plates of the frontal, the ethmoid between them, and the small wings of the sphenoid; and the posterior border of those wings separates it from the middle fossa. The *middle* fossa has a narrow mesial part formed by the pituitary fossa, and at each side it widens out and is floored by the great wings of the sphenoid and the upper surface of the petrous part of the temporal. The superior margin of the petrous separates the middle from the *posterior* fossa, which is walled by the inferior occipital depressions, the clivus, and the petrous and mastoid.

THE SHAPE OF THE SKULL.

The characters of the human skull are divisible into those which distinguish it from the skulls of apes, and those which vary according to age, sex, nationality and idiosyncrasy.

Distinctive characters. The most obvious is the huge development of the arch of the skull as compared with the base; the arch being expanded and the base mesially shortened. If the distance of the root of the nose or mesial end of the fronto-nasal suture from the back of the foramen magnum be taken to express the length of the base, and the distance between the same points as measured with a tape carried over the roof be called the arch, then the proportion borne by the arch to the base counted as unity varies for the most part in the human skull from 2·45 to 3, and is most frequently about 2·70; the general length of the adult male base-line being over five inches. The human cranium differs also greatly from that of all other animals in having the middle line of the floor of the anterior fossa basis cranii parallel to the plane of the foramen magnum, so that, regarded as part of the cerebro-spinal cylinder, it may be considered as completing in the adult state a semicircular curve. The face is elongated downwards from the cranium, so as to give height to the nasal fossae, affording space for the reverberation of the voice, which is further increased by the maxillary, frontal and sphenoidal sinuses, which are peculiar to man. In the lower animals, on the contrary, the nares are low and the jaws and palate elongated forwards in connection with the greater development of the teeth. But a just contrast of the size and form of the jaws of apes as compared with those of man can only be obtained when adult specimens are compared, as the face is in all animals later of development than the cranium. This obvious rule is too frequently set at nought, with the result of misleading the credulous who are willing to be deceived.

Variations. At different ages the form of the skull differs characteris-

tically, passing through a constant series of forms. During the latter half of foetal life the proportion borne by the base to the upper part of the skull gradually diminishes, till at birth it reaches the smallest proportion; and from that time it goes on increasing both in length and breadth. About a month before birth the parietal region reaches its maximum preponderance over the frontal and occipital; and these, but especially the frontal, henceforth grow more rapidly, till the adult proportions are reached. The roof is at birth, as also in the foetal state, elevated in the middle line, and uniformly undergoes in early childhood a flattening due to rise of the parietal and frontal eminences; but it again rises in adolescence. The angle at which the front of the face lies to the anterior fossa of the base (*orbito-nasal angle*) is greater at birth than afterwards, being afterwards diminished both in connection with increased growth of the whole lower forehead, and with projection forward of the outer table of the frontal when the frontal sinus makes its appearance. At birth each roof-bone extends conically from its eminence; and afterwards it becomes more uniformly rounded.

In old age there is a tendency to obliteration of sutures, and to absorption of diploe, especially in the parietals, and, next to them, the squamous parts of the temporals, and in the frontal and occipital; and also, by means of absorption, to enlargement of air-sinuses. The form also tends to change, in a manner to be accounted for by gravitation, and most marked when the cranial capacity is large without the bones being massive. Thus the base becomes transversely flat or slightly concave, the occipital tuberosity descends, the roof and forehead become lower, and the sides of the skull project out over the ears.

In the female special characters are observed less marked than those distinguishing the childish from the adult form, yet such as are attributable to non-participation in the later stages of male development. Thus the face is lighter, the occipital and frontal regions less developed in proportion to the parietal. Generally, the skull is lower; and the average proportion of breadth to length is less. Decidedly the most constant character is, as I pointed out, that the clivus forms larger angles than in the male with the planes of the foramen magnum and the anterior fossa of the base; the base having thus a *level* as distinguished from a *steep* form.

In different races the peculiarities of form are less constantly adhered to than those dependent on age and sex; but groups of peculiarities are to be found in different nationalities, and in individual skulls a certain number of these peculiarities are always present. Retzius divided races, according to the extent to which the longitudinal diameter of the skull surpassed the breadth, into *dolichocephali* and *brachycephali*. The Kaffir skull presents an instance of extreme dolichocephalic shape, and the Tartar races are examples of the brachycephalic, while in old British barrows, and even among stocks surviving in the British Isles, both

extremes are found. In recent years a great convention of questionable advantage has arisen, according to which the proportion of the greatest breadth to the greatest length taken as 100 is called the *cephalic index* or *index of breadth*, those skulls in which this index is below 75 being called dolichocephalic; those in which it is above 80, brachycephalic; and the intermediate proportions, mesocephalic. The *index of height* is, in like manner, an expression used to indicate the proportion of height from the front of the foramen magnum as compared with the length estimated at 100, and by it a classification can be made more closely corresponding with racial affinities. But more information is to be gained from the positive measurement of length and of height than from either of the indices mentioned.

In British skulls 7 inches is a common length; in the skulls of the Incas, who were an exceedingly brachycephalic race, the length may be under $5\frac{1}{2}$ inches. As to height, $5\frac{1}{2}$ inches is about the average, and the variations are confined between the limits of 5 and 6 inches. Breadth in uncivilized dolichocephalic races may be as small as 5 inches, and in Europeans is seldom so little, and may even exceed 6 inches. Retzius subdivided each of his great divisions after a method originated by Blumenbach, who had compared skulls by looking at them from above (*norma verticalis*) and observing whether the upper jaw projected beyond the forehead or not. Those with projecting jaw Retzius called *prognathous*, and those not projecting he termed *orthognathous*. The distinction is obvious and important: orthognathism is characteristic of civilized races, prognathism of savagery. Precision, however, demands that the elements on which the distinction depends be recognized. *Prognathous dentition* is the projection forwards of the teeth; and, in addition to this, deficiency of curvature of the base enters importantly into the production of prognathism by causing the floor of the anterior fossa of the base to rise in front, instead of being horizontal when the foramen magnum looks downwards. But a large angle between the front of the face and the floor of the anterior fossa of the base of the cranium (orbito-nasal angle) is neither characteristic of savagery nor of civilization; it is largest of all in the French, and also large in the Scotch, while the Germans and Irish have it remarkably small (Cleland, *Phil. Trans.*, 1869). In the lower races, breadth from one zygoma to the other (*malar breadth*) often exceeds the greatest breadth of the cranium, but in civilized races never. Also in the lower races the position of greatest cranial breadth is liable to be situated not far below the parietal eminences, while in civilized races it is nearer the squamous suture, above or a little behind the ear. The aperture of the anterior nares varies in shape, being short and wide in the negro, long and narrow in the American Indian. In markedly prognathous skulls there is usually a *subnasal depression* beneath each nostril. The shortest base line from the back of the foramen magnum to the fronto-nasal suture, 5 inches and under, is found in the

females of civilized nations, the longest, up to nearly 6 inches, in males of savage race.[1]

Individual peculiarities or **idiosyncrasies** tend to affect the roof more than the base. Thus individually large skulls differ from others by elongation and broadening of the vault, the former circumstance depressing the external occipital protuberance in relation to the plane of the foramen magnum, and still more in its apparent position during life, in consequence of the increased weight of brain taking place in such a manner that the head is more thrown back in balancing it. Sometimes an unusual separation of the frontal eminences, with consequent increased breadth of forehead at the coronal suture to such an extent as almost to equal the greatest breadth of the whole cranium, occurs in conjunction with permanence of the frontal suture, as if increased growth of the fore part of the brain had led to that suture remaining open; though it is to be noted that there is another set of skulls with open frontal suture in which no deviation from the usual form is present.

Local differences in surface-form (*bumps* of popular phraseology) are of infinite variety. The skull is never perfectly symmetrical, and in some individuals the want of symmetry is very marked. Other peculiarities arise from circumstances more or less pathological, especially from *synostosis*, or premature closure of sutures which usually remain open. Thus there is a characteristic Cretin skull,[2] dependent on premature synostosis of the base. In another deformity, called *scaphocephalus*, the arch is low and enormously elongated in the parietal region, which is also low and narrow, the whole peculiarity depending on prenatal obliteration of the sagittal suture, and growth at the lambdoidal and coronal sutures to compensate; so also *trigonocephalus* with sharp mesial prominence of a narrow forehead, results from early obliteration of the frontal suture (Welcker). A high form, *acrocephalus*, with shallow orbits, depends in like manner on synostosis of the lateral parts of the coronal suture.

The **cranial capacity** owes its interest rather to affording an approximate indication of the bulk of the encephalon than to its osteological importance. Much precaution is necessary for its correct estimation, and probably the method first used by Allen Thomson, filling the skull with turnip seed, is the most accurate and convenient. The cranial

[1] In making racial measurements, a series of words mostly new have come into use, among which may be mentioned *nasion*, the middle of the fronto-nasal suture; *obelion*, the vertex; *ophryon*, the glabella; *bregma*, the middle point of the coronal suture; *lambda*, the apex of the lambdoid suture; *inion*, the external occipital protuberance; *basion*, the front of the foramen magnum; *opisthion*, the back of the foramen magnum; *pterion*, the position of the spheno-parietal suture; *stephanion*, the point where the temporal ridge crosses the coronal suture; *asterion*, where the occipital fits in between parietal and mastoid.

[2] First described by Virchow, who, however, was completely mistaken as to the nature of the deformity, attributing it to increased curvature of the base and calling it *kyphosis*. It presents, as I pointed out, greatly deficient curvature of the base.

capacity has been estimated to vary normally from 60 to 110 cubic inches, and to be from 85 to 88 cubic inches in the average European male, and in the female about 5 inches less. It varies also according to stature, and in the lower racial types is diminished, thus reaching a minimum in the slightly-built and dwarfish Bosjes, Andaman Islander and Veddah. It is small in various negro races and in Australians.

MOVABLE ARTICULATIONS OF THE SKULL.

The articulation of the occipital bone with the atlas and axis has been already considered (p. 124).

The temporo-maxillary articulation presents two synovial cavities separated by a fibro-plate.

The interarticular fibro-plate, or so-called fibro-cartilage, is a firm structure thicker behind than in front. Its upper surface is concavo-convex from before backwards, so as to fit into the concavity as well as the convexity of the articular surface of the temporal bone. Its under surface is concave, fitting to the condyle of the lower jaw, and closely connected with it at the outer and the inner edge.

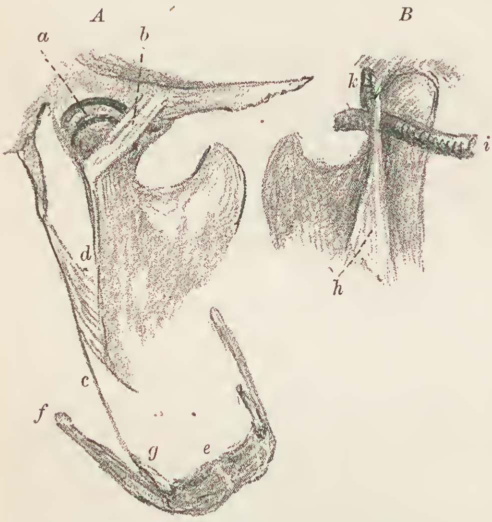


FIG. 222.—TEMPORO-MAXILLARY ARTICULATION AND HYOID BONE. *A*, Joint from the outer side, hyoid appended. *B*, Joint from inner side. *a*, Interarticular disc; *b*, external lateral ligament; *c*, stylo-hyoid ligament; *d*, stylo-maxillary ligament; *e*, body of hyoid bone; *f*, *g*, great and small cornu; *h*, internal lateral ligament; *i*, internal maxillary artery; *k*, middle meningeal artery.

The synovial membrane above the fibro-plate is looser than that between the fibro-plate and the lower jaw.

The fibrous capsule has its fibres placed vertically behind and also on the sides, while in front they pass inwards to the sphenoidal border of the temporal surface and are closely connected both with the fibro-plate and the external pterygoid muscle.

The external lateral ligament is an oblique band strengthening the fibrous capsule and stretching from the tubercle at the root of the zygomatic process, downwards and backwards to the posterior edge of the outer surface of the neck of the lower jaw.

The internal lateral ligament is a strong membranous band extending from the spinous process of the sphenoid bone to the lingula of the inferior dental foramen, and separated from the capsule by the internal maxillary vessels and the auriculo-temporal and inferior dental nerves. It

is a band connected in the foetus with the perichondrium of Meckel's cartilage, but is not without ligamentous function.

The stylo-maxillary ligament is merely a band of fascia extending from the styloid process to the angle of the lower jaw, between the parotid and submaxillary glands.

Movements of the jaw. The principal movements are of a hinge kind, opening and shutting the mouth, but differ from those of other hinge-joints in that the condyle is moved forwards out of the glenoid cavity on to the convexity in front, every time that the mouth is opened, and retreats in closing it, as can be felt on placing a finger in front of one's own ear. In accomplishing these movements the upper and lower compartments of the joint take different parts, the fibro-plate moving forwards and backwards on the temporal articular surface, while the condyle revolves in the concavity of the under surface of the fibro-plate. In opening the mouth both the external and internal lateral ligaments are tightened and become factors in pushing the condyle of the jaw forwards by limiting backward movement at their lower attachments.

Two other kinds of movement of the jaw are allowed. In one, the jaw is pushed forwards and backwards, protracted and retracted by movement of the fibro-plate on the temporal bone, while the lower compartment of the joint is passive. In the other, the oblique or grinding movement, the condyle of one side is, together with the fibro-plate, drawn forwards; and the other condyle remaining in the glenoid cavity, there is at the same time a circular movement, the protracted condyle moving round the other, and likewise carrying with it the fibro-plate.

DEVELOPMENT OF THE SKULL.

In the early embryo the notochord ends in a pointed extremity curving in a ventral direction underneath the first cerebral vesicle, and soon interfered with and shortened at the point by the cerebral and stomodaeal pouches which cohere to make up the pituitary body (p. 98); but it can be traced in the posterior sphenoidal region for a considerable time. "The first cartilaginous rudiments appear in the primitively membranous skull tube in the form of a pair of rods, the *trabeculae cranii.* These lie along the base of the brain, their posterior part embracing the notochord; and they thus are divisible into *prochordal* and *parachordal* regions."[1] The

[1] Wiedersheim, *Elements of Comparative Anatomy adapted by W. Newton Parker* (p. 57). I have preferred to use these words because they make it clear that admittedly there is no radical difference in the nature of the fore part of the mesial bars of the skull from that of the hinder part. The intrusion of the fore part of the pituitary body from below, however difficult to explain in the present state of our knowledge, does not do more than open up a mesial division between the right and left halves of longitudinally arranged structures. It may be noted in this connection that in seals there is often a mesial perforation of the basilar process of the occipital, and that it is frequent when spina bifida involves large portions of the spinal column to find series of vertebrae with their bodies in two lateral parts separated one from the other.

prochordal parts, to which the name trabeculae is more strictly confined, pass forwards, one on each side of the pituitary body, to end in the frontonasal region in *cornua* turning outwards. The parachordal parts, which would appear to be at a certain period distinct from the prochordals, unite around the notochord, and send an extension on each side round the foramen magnum and thence forwards round the internal ear. The prochordal parts unite first in front of the pituitary fossa, and afterwards floor it. The mesial bar thus formed in front of the pituitary fossa is the source of the fore part of the body of the sphenoid and of the whole septum of the nose, while the cornua go to the formation of the lateral nasal cartilages; and by lateral outspread further back the cartilaginous basis of the great and small sphenoidal wings and of the lateral masses of the ethmoid is laid down. The development of cartilage is confined to the lower part of the cranium, but I find it extending a small way on the inside of the lower part of the supra-occipital element, and also inside the back part of the squamous portion of the temporal.

Beneath the cranium there are three pairs of cranial bars. The foremost was observed by Kitchen Parker in the pig, developed in the maxillary lobe, short and feeble, in the region of the palate and pterygoid bones. The others are the *mandibular and hyoid arches*; and at their base there is at first one continuous cartilage which soon becomes divided into malleus and incus (and stapes, etc.); while from the malleus a bar, *Meckel's cartilage*, is continued down to meet its neighbour at the symphysis, and can be traced as late as the fourth and fifth months in close connection with the mandible, which is formed superficial to it, while the upper part persists as the processus gracilis of the malleus. The hyoid arch at an early period forms, like Meckel's cartilage, a complete cartilaginous bar continuous with its fellow of the opposite side. It is developed in the second visceral or poststomal lobe of the embryo (p. 98), its lower part forming the body and small cornu of the hyoid bone, and remaining continuous, till at least the end of the third month, with the upper part, the styloid process of the temporal bone.[1]

Fig. 223.—Part of Base of Skull of Foetus of Four Months. *a*, Right squamous; *b*, cartilaginous incus with stapes continuous with it; *c*, malleus with Meckel's cartilage proceeding from it on inner side of *d*, the lower jaw; *e*, an early and constant continuity of the cartilage of the mastoid with the short process of the incus and the hyoid arch; *f*, cartilaginous petrous; *g*, fenestra rotunda.

[1] The upper connections of the styloid part of the hyoid cartilage require further investigation. Reichert described this cartilage as continuous with the stapes, but Fraser has pointed out that this is a mistake. I have verified Fraser's observations; and undoubtedly the connection seen by Reichert is not cartilaginous but only the

Ossification. The *occipital*, as already stated, consists at birth of a basilar, two lateral and a superior portion. To the basilar part belong the basilar process and fore parts of the condyles; the lateral portions bound the foramen magnum on its sides, and to them belong the jugular processes and greater part of the condyles; the superior or tabular portion reaches to the foramen magnum in the middle line, and forms the expanded part of the bone. The basilar and lateral portions have each one centre of ossification appearing in cartilage about the end of the second month; the superior portion has four centres all appearing in membrane prior to the others, and becoming soon united, the upper pair corresponding with the interparietals, seen in many mammals, *e.g.* the sheep. The superior part of the occipital becomes united to the lateral in the second year, and the lateral parts to the basilar by the sixth year. The anterior condyloid foramen, originally in front of the lateral portion, is completed by growth forwards of the supraforaminal ridge.

Fig. 224.—Occipital Bone at Birth.

The *parietal* probably begins to ossify about the seventh week. It soon appears to consist of one centre of ossification radiating from the parietal eminence; but, as pointed out by Toldt, there is a second and lower centre, the network formed by which can be discerned, forming a distinct pattern at the lower and back part for a considerable time. This explains the rare anomaly of two parietal bones on one or both sides. The parietal foramen is originally a deep gap open towards the middle line, and with its fellow of the opposite side has been described, unnecessarily enough, as a *sagittal fontanelle* closed before birth.

The *frontal* also probably begins to ossify about the seventh week. It has one centre of ossification corresponding with each frontal eminence. The two frontals thus formed are separated by the frontal suture which persists till the seventh or eighth year, and sometimes throughout life (p. 243). Three supplementary centres on each side have been noted (Testut).

The *sphenoid* has a pair of osseous centres in the posterior part of the body (*postsphenoid*), a smaller pair in the anterior part (*presphenoid*), and an independent centre in each ala. The centres of the great alae (*ali-*

rudiment of the stapedius muscle; and possibly it may be the same structure which Salensky figures as uniting the long process of the incus with the hyoid cartilage. But in the third and fourth months the hyoid cartilage, though united to the front of the mastoid part of the cartilaginous cranium, can be followed up into continuity with the posterior process of the incus; and in many adult mammals it can be seen that this continuity is only broken by articulation. The stapes is generally supposed to originate from the wall of the labyrinth. My dissections have satisfied me that it is primarily continuous with the incus, and afterwards applied to the petrous. (See Cleland, *Memoirs and Memoranda in Anatomy*, 1889.)

sphenoids) appear about the eighth week, and from them are ossified the great wings and the external pterygoid plates. Soon after, the nuclei of the small wings (*orbitosphenoids*) appear external to the optic nerves, and extend inwards embracing them, and these are followed by the nuclei of the postsphenoid. The postsphenoid nuclei rapidly unite, while the presphenoid nuclei unite not only one with the other, but with the orbitosphenoids. About the seventh month the postsphenoid and presphenoid become joined together, leaving for a while a cylindrical column of cartilage in the middle, descending from the sella turcica to the back part of the septal cartilage of the nose. The alisphenoids remain distinct from the body for a considerable time after birth; but already, in the fifth month of foetal life, have the separately ossified internal pterygoid plates adherent to them below the Vidian canals. The lingula has been found to have a separate centre of ossification (Sutton), and sometimes remains distinct through life (Debierre). The sphenoidal turbinated bones, as already pointed out, constantly present in early life four centres each, which combine to form a pair of hollow cones.

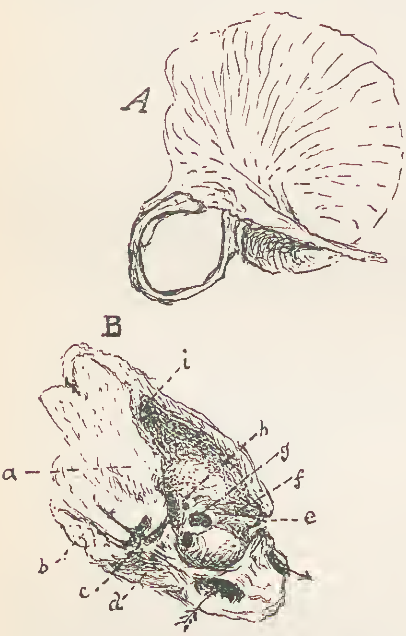


Fig. 225.—Right Temporal at Birth, $\frac{4}{5}$. *A*, Squamous portion with adherent tympanic plate in the form of a thin ring almost surrounding the external auditory meatus. *B*, Petro-mastoid separated from the squamous by breaking through the slight union. *a*, The mastoid process scarcely as yet projecting; *b*, surface for articulating with jugular process of occipital; *c*, stylomastoid foramen, and the groove from which emerged the as yet cartilaginous styloid process; *d*, jugular fossa; *e*, cochleariform process; *f*, fenestra rotunda; *g*, fenestra ovalis; *h*, opening in the pyramid for tendon of stapedius; *i*, edge of contact of the mastoid with the squamous in front of the recess in continuity with which the mastoid cells are afterwards developed. A bent arrow indicates the carotid canal.

The *temporal* has its petromastoid and styloid centres originating in cartilage, while its squamous and tympanic parts are ossified from membrane. The petrous begins to ossify in the fifth month from an elongated centre placed between the fenestra ovalis and fenestra rotunda, and rapidly extending in a twisted form forwards round the cochlea and backwards round the vestibule. From this main centre there are subsequent laminar extensions, one set of which forms the tegmen tympani, the roof of the internal auditory meatus, the tympanic wall of the aqueduct of Fallopius, and the bony flap covering the aqueducts of the vestibule and cochlea, while another forms the floor of the tympanum and stretches inwards to complete the carotid canal. Additional nuclei have been described in connection with the superior and posterior semicircular canals, but do not appear to be con-

stant as distinct centres.[1] The ossification of the root of the styloid process is distinct, appearing before birth, and can be traced upwards in various mammals at a late date to the point of attachment of the posterior process of the incus. The later elongation of the styloid process can often be seen in childhood as a separate centre. The squamous centre appears, like the other roof-bones, towards the end of the second month. The tympanic centre appears in the third month in the form of a delicate ring imperfect above. It becomes united before birth to the squamous; but its most extensive development is later, and takes place in an outward direction. This outward extension is completed at first in front and behind, leaving for a time, in young skulls, a gap in the floor of the external auditory meatus.

The *ethmoid* begins to ossify in the lateral masses from scattered and irregular nuclei in the fifth month of foetal life. About a year after birth ossification commences in the base of the crista galli, and extends in the vertical plate and outwards in the cribriform. As a general rule, in mammals, the cribriform plate appears to be formed altogether in this way; but in the human subject it makes rapid progress while even the upper edge of the central plate is imperfectly ossified, and it has separate nuclei which may be counted as common to it and the lateral masses.

The superior maxillary begins early to ossify, being, it is alleged, preceded only by the clavicle and lower jaw. The ossific bars radiate from a position external to the nasal notch. It has long been a subject of dispute whether the intermaxillary part has a separate centre of ossification, and recent observers have exhibited specimens to show it as a separate bone up to the fifth month; but it is granted that the anterior wall of the sockets of the incisor teeth is ossified from the superior maxillary proper. In connection with this it may be noted that the outer incisor teeth lie in front of the palatal cleft which limits the intermaxillary part behind, and have their sockets in other animals wholly formed by the intermaxillary bone; and yet, when developed in cases of cleft palate, they are external to the cleft. In completely cleft palate the intermaxillaries are developed in the mesial process in continuity with the vomer.[2]

[1] Kerckring (*Spicilegium Anatomicum*, 1870, pp. 222, 223), whose description in the original Latin is transcribed by Huxley (*Lectures on Comparative Anatomy*, 1864), describes correctly the nucleus of the petrous, and adds that in the fifth month three other nuclei appear in the mastoid region. Huxley curiously misinterprets Kerckring, alleging the three additional centres to include the petrous, which is mentioned and figured by Kerckring as distinct from them when these were seen separate. There is no real ground in human anatomy for the expressions *pro-otic*, *epiotic*, and *opisthotic*, which took rise in Huxley's description; but this is not the place to discuss how erroneous they are in comparative anatomy.

[2] Comparative anatomy favours the view maintained by some that the intermaxillary elements have a twofold source, one related to the maxillary lobe, and the other to the fronto-nasal. I long ago (*Phil. Trans.*, 1862) pointed out that throughout the vertebrata there are to be distinguished the lateral element and mesial palatine

The *palatal and nasal* bones each ossify from a single centre later than the superior maxillary. The *vomer*, about the same time, is ossified from a pair of centres which soon unite. The *malar* is stated to have three centres of origin which speedily unite (Testut). The *inferior turbinated* begins to ossify in the fifth month of foetal life.

The *lower jaw* is, next to the clavicle, the earliest bone to show osseous deposit. It is developed round Meckel's cartilage, mainly outside of it; but additional centres have been noted at the lingula, at the angle, at the coronoid process, and at the condyle. The condyle is laid down in cartilage before its ossification begins, but the supposition that Meckel's cartilage is in any part converted into osseous tissue of the jaw is erroneous.

The fontanelles. The *anterior fontanelle* (*bregma* of old writers) is a diamond-shaped gap in the osseous roof of the young skull where the

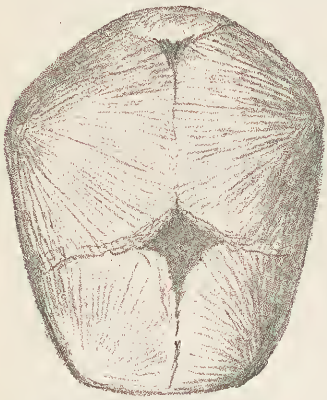


Fig. 226.—Skull at Birth, from above, showing anterior and posterior fontanelles.

Fig. 227.—Skull at Birth, right side, showing a considerable postero-lateral fontanelle, and no antero-lateral.

frontal, sagittal, and coronal sutures meet. It remains open till about the end of the second year, and has an obvious pulsation communicated to it by the intracranial arteries. The *posterior fontanelle*, situated where the sagittal and lambdoidal sutures meet, presents at birth only a slight three-sided space; but the occipital and parietals are at that time sufficiently loosely connected to allow the tip of the occipital to be pressed below the margin of the parietals in the passage of the child's head through the pelvis, so that the spot is easily detected with the fingers by the accoucheur. *Antero lateral* and *postero-lateral fontanelles* have also been described at the inferior angles of the parietals, but there is no constant deficiency in the osseous walls at these parts.

element found in mammalian intermaxillaries, while birds have a mesial ascending element in front of the nostrils; and that in the fish the intermaxillary, so-called, is a purely lateral element, while the mesial elements take part in the formation of the prevomerine bone (nasal of Owen), closing in the cranium in front and containing in addition a nasal element.

THE MUSCLES.

The tissue of the voluntary muscles forms the red flesh of the body. It is composed of fibres which are collected into bundles surrounded by delicate sheaths of connective substance; the bundles of fibres are aggregated together into masses which are more or less distinctly separated from one another by the investing fibrous tissue, and constitute the individual muscles. Among the muscles there is much variety of form; some are broad expanded sheets, others are compact and rounded, and there are many varieties of shape. A muscle is an elastic organ which possesses the power of contraction, and each individual muscle has definite connections or attachments. Certain muscles form ring-like bands which surround the margins of openings; they are named sphincters; by their elasticity they oppose the dilatation of, and by their contractility they diminish or close the apertures which they encircle. Others, entering into the construction of curved walls, by their elasticity offer opposition to forces which tend to increase the curvature of the surfaces which they cover; contracting, they flatten out the curves and remove or produce pressure. The diaphragm, the broad muscles of the abdomen, and possibly also the platysma myoides, offer examples of this type of muscle. Most of the muscles are more or less strap-shaped. The great majority are attached at both their extremities to portions of the bony or cartilaginous framework and cross over joints; contracting, they produce movements at the joints; by their elasticity they assist in maintaining the bones in apposition, and resist movement. They are arranged in groups which oppose and balance one another, and the deeper members of a group are usually short, and as a general rule stretch over one joint only, while the more superficial are long, and may cross over two or more joints. In the various movements of the body every variety of lever is employed, and the same muscle may be used in different actions to move different orders of levers, according as a part is free to move or is made to serve as a fulcrum.

The methods of attachment of the muscles to the bones are various. Some muscles spring directly by fleshy fibres, others indirectly by means of *tendons*, which may either be compact structures presenting the characteristic peculiarities of tendinous texture, or expanded membranously as *aponeuroses*. Of the two attachments of a muscle, that which in the usual movements which the muscle subserves is the fixed point is commonly called the *origin*, while the other is the *insertion*; but on account of the numerous and varied kinds of bodily movements in which any individual muscle may take part, it is impossible to apply the terms with scientific accuracy, and they are used, to a large extent, in an arbitrary fashion for convenience of description.

Muscles differ from one another in the number, length and direction

of their fasciculi, or bundles of fibres. Comparing with regard to the extent and power of their contraction muscles of equal bulk, that in which the fasciculi are long, and stretch from end to end of the muscle, will produce the greater extent of motion; that in which the bundles are shorter, more numerous, and oblique in their direction, will produce a smaller amount of motion, but will contract with greater power. The action of any individual muscle may be demonstrated in the body by approximating its attachments to one another, but it is seldom that a muscle acts individually, even in the simplest movements groups of muscles being called into play. Muscles which stretch over one joint are comparatively simple in their action; but in the case of those which pass over more than one joint, it is necessary before they can exert their power on any one particular joint that their actions on the other joints over which they pass should be neutralized and balanced by the contraction of opposing muscles. Very many of the muscles cross over more than one joint, one of the advantages of the arrangement being that muscles, longer and more powerful than those the fibres of which simply pass between neighbouring skeletal pieces, are obtained and can exert their force upon parts comparatively distant; thus the slender digits are under the control of powerful muscles situated in the fleshy parts of the limbs. Muscles which pass over more than one joint play an important part as ligaments, and as such, without contracting, bring about during movements at the proximal joint simultaneous and opposite movement at the distal joint. Taking for the sake of example the muscles of the thigh: when the hip is flexed by the action of its special flexor muscles, the long muscles behind which pass over the hip and knee, acting simply as ligaments, produce a simultaneous flexion at the knee, and conversely, when the hip is extended, the long muscles in front extend the knee. In the habitual movements and in the maintenance of the sustained positions of the body, the ligamentous action of the long muscles is specially important. On the other hand, the full contraction of these muscles is exhibited in the passage from one extreme of position to another, as in the movements associated with throwing a stone or kicking a football. In all the movements of the body, except those of the very simplest kind, simultaneous or nearly simultaneous action is taking place at a number of joints. The student will readily perceive that the study of the bodily movements, from the point of view of the muscles which produce them, is a very complicated one.

Fasciae. The connective tissue of the body forms membranous sheets which underlie the skin and surround and separate from one another the muscles. To the membranous tissue which lies immediately under the skin the name *superficial fascia* is given; it is formed of two layers, the more superficial of which contains, in many cases, in its meshes a considerable quantity of fat; the deeper, which is comparatively free from fat, supports the trunks of the cutaneous vessels and nerves. In the

superficial fascia of the eyelids, the penis and scrotum there is no fat; in that of the buttocks and abdominal wall the layer of fat, especially in females, is often of considerable thickness. The superficial fascia is continuous all over the surface of the body; the details of its arrangement in one or two regions, the lower part of abdominal wall, the upper part of the thigh, etc., are of surgical importance, and will be specially described along with those of the muscles and the deep fascia.

The *deep fascia* covers the muscles superficially, and sends processes and septa between them; it varies much in strength and consistence in the different regions of the body, and often affords a surface of origin or insertion to muscular fibres. When much strengthened, it becomes aponeurotic in its nature. It will be specially described along with the muscles in each region. In many places in the body there are in the tissue spaces which are lined by synovial membrane; these are termed *bursae*. They usually serve to facilitate the gliding of muscles or tendons over prominent surfaces of bone; bursae are also found in the subcutaneous tissue between the skin and the more prominent structures beneath it. Tendons which are passing over pulleys or through narrow canals are usually surrounded by delicate connective tissue sheaths, which are lined by synovial membrane, and are termed *synovial sheaths*.

MUSCLES OF THE UPPER LIMB.

MUSCLES CONNECTING THE LIMB WITH THE TRUNK.

These muscles may be arranged in a posterior and an anterior group. Those of the posterior group are the trapezius, latissimus dorsi, levator anguli scapulae, and the rhomboidei; those of the anterior group are the pectoralis major, the pectoralis minor, the serratus magnus, and the subclavius.

The **trapezius** arises from the tips of the spines and the supraspinous ligament of all the dorsal and the seventh cervical vertebrae, the ligamentum nuchae, the external occipital protuberance, and the posterior third of the superior curved line of the occipital bone. Its fibres converging are inserted into the posterior border of the outer third of the clavicle, the inner edge of the acromion, and the upper edge of the spine of the scapula. The origin and insertion take place for the most part by short tendinous fibres; of the fibres of origin those arising from the seventh cervical spine and for a little distance above and below that point are slightly longer than the others. The connection with the occipital bone is aponeurotic in character. The lowest fibres of insertion form a flat tendon which glides over the triangular area at the base of the scapular spine, a bursa being occasionally interposed.

The muscle covers portions of the latissimus dorsi, infraspinatus, and rhomboideus major muscles, and conceals the rhomboideus minor, levator

scapulae, and supraspinatus. On its deep surface lie the superficial cervical artery, and the nerves from which it receives its supply, namely, the spinal accessory and some branches of the cervical plexus.

The trapezius is subject to a number of variations. Above, it sometimes

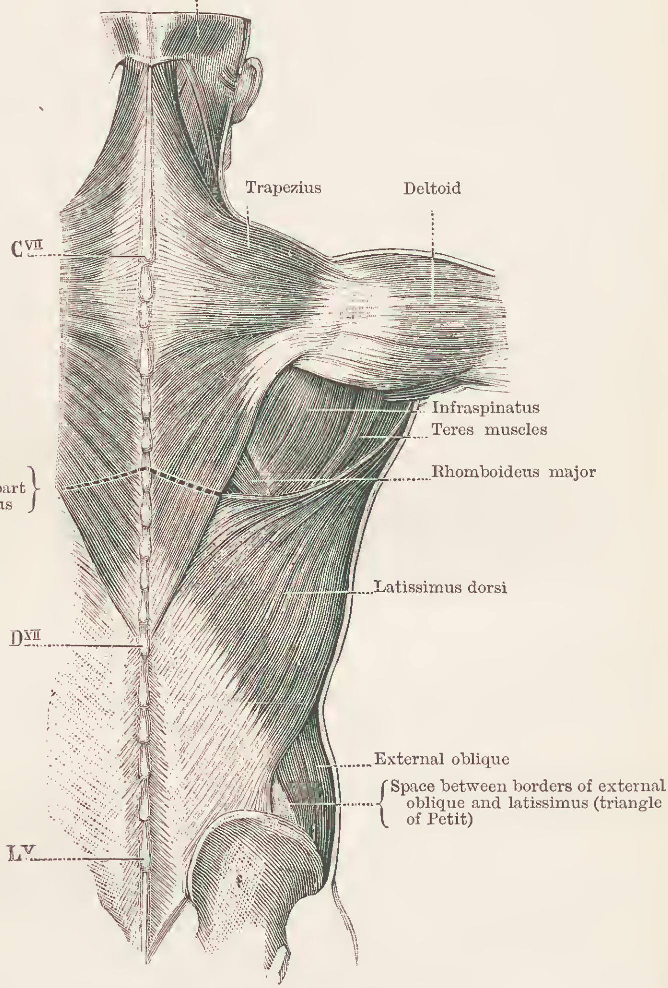


FIG. 228.—THE SUPERFICIAL MUSCLES OF THE BACK. (L. Testut.)

falls short of the skull, and below, occasionally extends no further than the ninth or tenth dorsal spine. In the neck it is sometimes found connected with or united to the sterno-mastoid muscle.

The **latissimus dorsi** has a very broad origin, but its fibres rapidly converge as they pass upwards and outwards to the insertion. It springs (*a*) from the spines and supraspinous ligament of the lower five or six dorsal

vertebrae, (*b*) from the posterior layer of the lumbar aponeurosis, by means of which it is connected with all the lumbar and sacral spines and the outer lip of the posterior third of the iliac crest, (*c*) from a small portion of the crest in front of the limit of the attachment of the lumbar aponeurosis, (*d*) from the lowest three or four ribs by fleshy slips which interdigitate with slips of the external oblique muscle, and (*e*) in many cases by a few fibres at its upper border from the fascia covering the lower angle of the scapula. It is inserted by a tendon about an inch and a half in breadth into the floor of the bicipital groove of the humerus. The muscle crosses behind the lower angle of the scapula and covers the teres major at its origin, but passing further outwards folds completely round the lower border of the teres major and becomes applied to it anteriorly, taking part with it in the formation of the posterior wall of the axilla. The muscle becomes tendinous two or three inches from the insertion, and the tendon is at first in close contact with that of the teres major, but near the bone a bursa is interposed between them. The latissimus is covered at its upper part posteriorly by the trapezius, but further outwards an angular interval, sometimes alluded to as the "auscultatory triangle," is left between the borders of the two muscles and the edge of the rhomboideus major. The outer margin of the part of the muscle which springs from the iliac crest frequently overlaps the posterior margin of the external oblique muscle; but, on the other hand, in many cases there is left between the borders of the two muscles a space in which a portion of the internal oblique is exposed. The nerve of supply is the long subscapular from the posterior cord of the brachial plexus; it is to be found on the deep surface of the outer part of the muscle. Occasionally muscular bands are prolonged from the latissimus across the axillary vessels to the muscles of the anterior wall of the axilla, or downwards to the muscles and fascia of the inner and back part of the arm.

The **rhomboideus major** arises by short aponeurotic fibres from the spines and interspinous ligaments of the second, third, fourth, and fifth dorsal vertebrae; it is inserted into the vertebral border of the scapula in the region between the root of the spine and the lower angle of the bone. The greater number of the fibres do not directly reach the bone, but pass into one or more tendinous bands concealed within the muscular substance and lying close to the scapular margin to which at their extremities they are attached.

The **rhomboideus minor** springs from the lower end of the ligamentum nuchae and from the spines of the last cervical and first dorsal vertebrae. It is inserted into the vertebral border of the scapula at the root of the spine.

The rhomboidei together form a four-sided fleshy mass directed downwards and outwards, covered posteriorly in the greater part of its extent by the trapezius, overlapped at the lower and outer angle by the latissimus dorsi, but appearing superficially in the narrow area between

their borders. They are supplied by a special nerve from the brachial plexus. From the upper margin of the rhomboideus minor a muscular slip occasionally passes to the atlas or to the occipital bone.

The **levator anguli scapulae**, completely covered by the trapezius, arises by tendinous slips from the posterior tubercles of the transverse processes

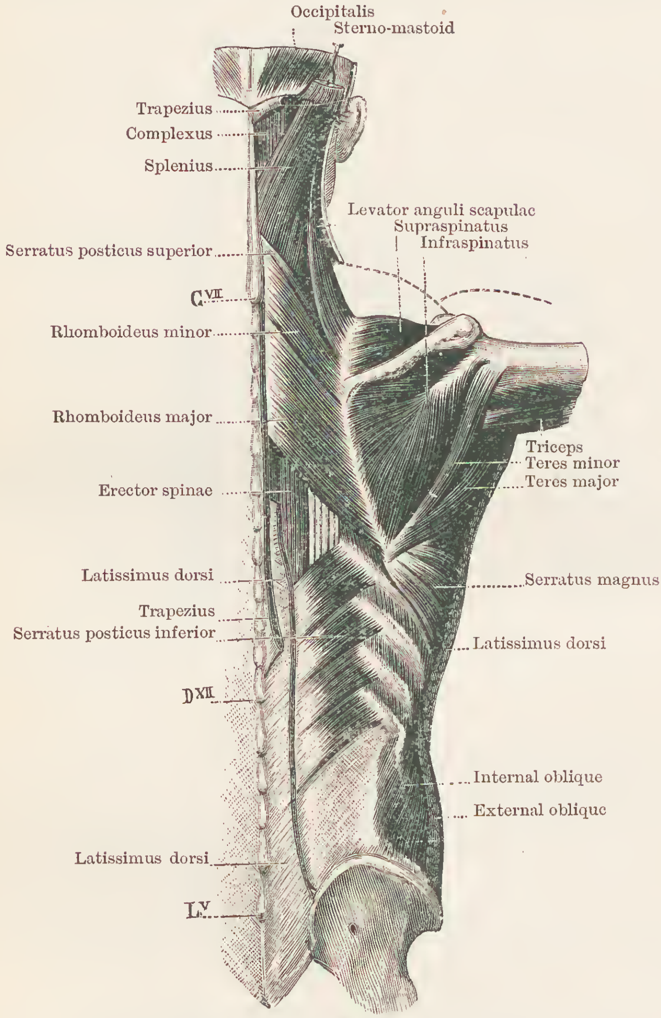


Fig. 229.—Second Layer of Muscles of the Back. (L. Testut.)

of the first four or five cervical vertebrae, and is inserted into the vertebral border of the scapula in the region between the upper angle and the root of the spine. It is supplied by two or three small branches from the cervical and brachial plexuses. Occasionally the muscle is connected by a slip with the serratus magnus.

The **serratus magnus** (*serratus anterior*) arises by fleshy slips from the

outer surfaces of the first eight ribs near their anterior extremities. Converging considerably, the fibres are inserted into an area of the ventral surface of the scapula which lies close to the vertebral border of the bone. From the first and second ribs a thick slip forming the upper edge of the muscle passes backwards and slightly upwards to a rough area near the

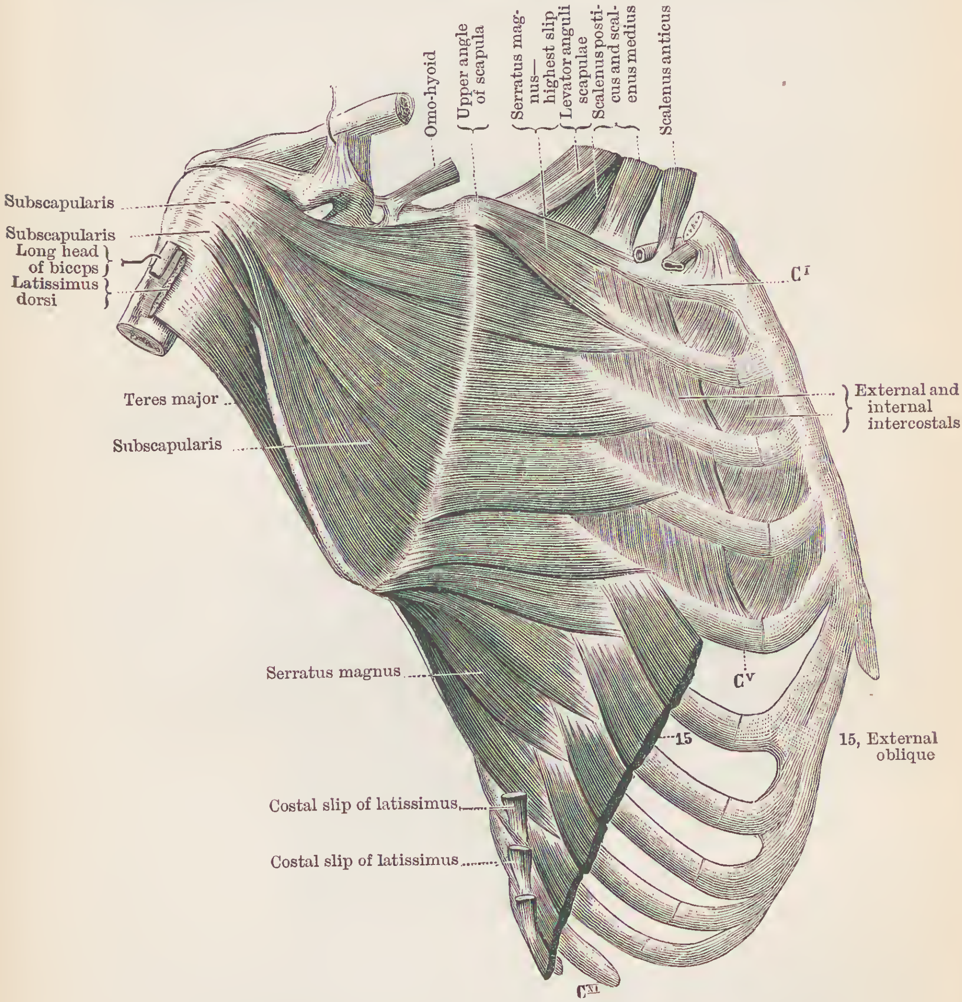


FIG. 230.—THE SERRATUS MAGNUS AND NEIGHBOURING MUSCLES. (L. Testut.)

upper angle; from the second and third ribs two broad thin slips pass downwards and backwards to a narrow line which connects the upper and lower rough impressions; the remaining slips converge rapidly to form a thick mass which is inserted into the large triangular area in front of the lower angle. The lower slips interdigitate at their origin with those of the external oblique muscle. The inner surface of the muscle is in close con-

tact with the ribs, and covers a portion of the serratus posticus superior muscle. The outer surface forms the inner wall of the axilla, and upon it lies the nerve of supply—the posterior thoracic branch of the brachial plexus.

The **pectoralis major** arises by short tendinous fibres from the anterior surface of the sternum, the cartilages of the first six or seven ribs, and

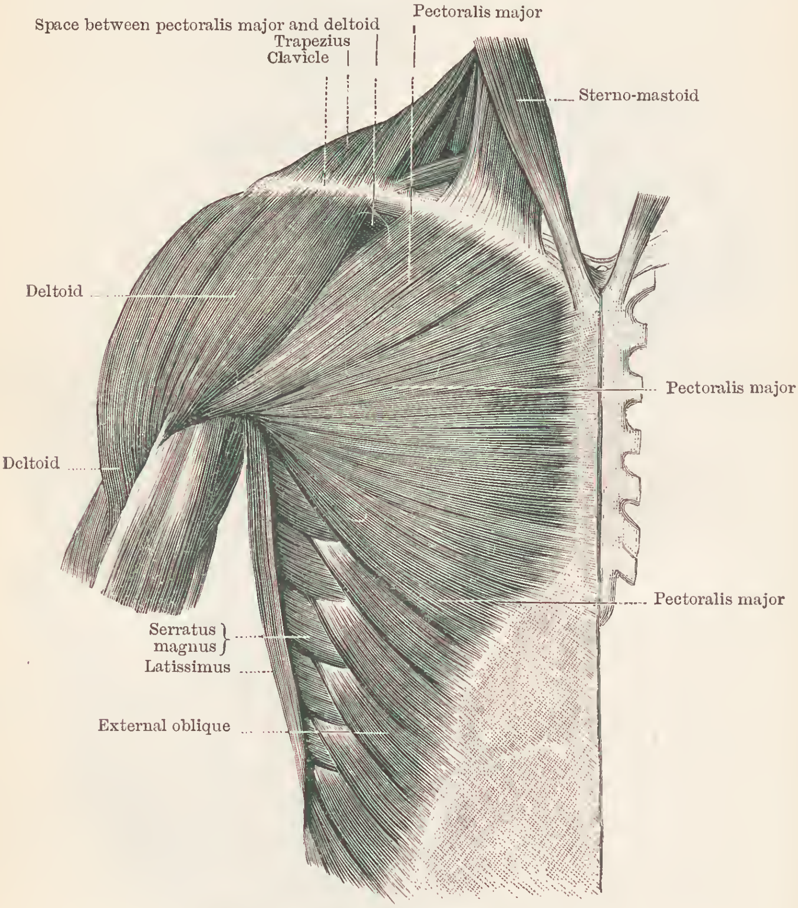


Fig. 231.—Superficial Pectoral Region. (L. Testut.)

the upper part of the sheath of the rectus abdominis muscle, and by a fleshy slip from the anterior surface of the inner half of the clavicle. It is inserted by a strong folded tendon into the outer or anterior lip of the bicipital groove of the humerus. The muscular fibres converge as they pass outwards, and in crossing the axilla those of the pectoral part are folded upwards behind the others to such an extent that the posterior lamina of the tendon reaches a little higher on the bone than the anterior.

Aponeurotic fibres are prolonged from the upper edge of the tendon to the capsule of the shoulder-joint, and from the lower edge to the insertion of the deltoid muscle. The insertion is slightly overlapped by the anterior margin of deltoid. The external anterior thoracic nerve and a branch from the internal anterior thoracic enter the muscle on its deep surface.

A small muscular slip, the *sternalis muscle*, is occasionally present on one or both sides of the body, lying upon the surface of the pectoralis major along the edge of the sternum. An additional slip along the lower edge of the muscle occasionally descends for some distance in the arm.

The **pectoralis minor** arises from the outer surfaces and upper borders of the third, fourth, and fifth ribs near their anterior extremities. It is

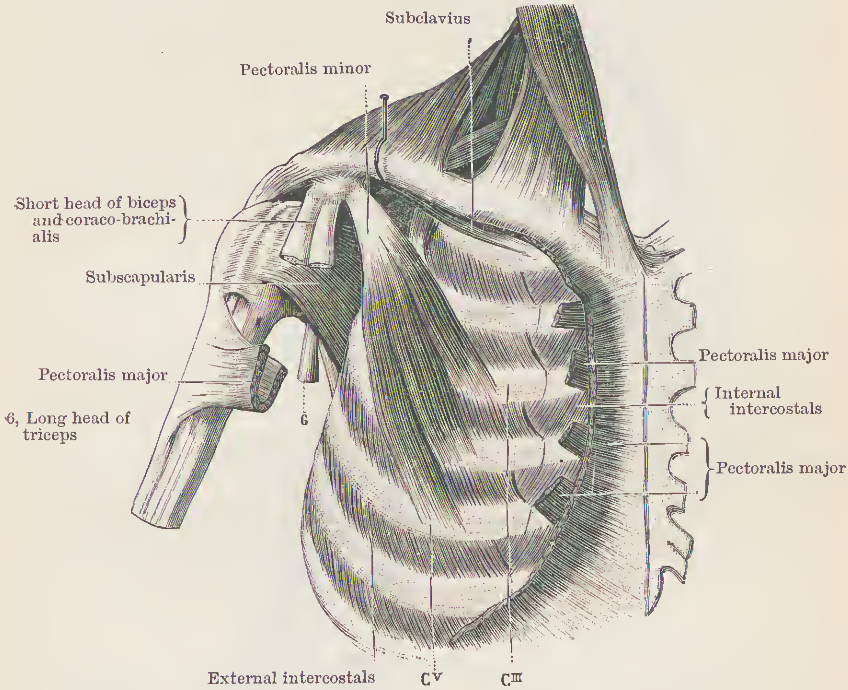


FIG. 232.—DEEP PECTORAL REGION. (L. Testut.)

inserted into the inner border and upper surface of the anterior half of the coracoid process of the scapula. The insertion takes place by a flat tendon continuous at its outer edge with that of the short head of the biceps and the coraco-brachialis. The muscle lies under cover of the pectoralis major, and forms part of the anterior wall of the axilla. It is supplied by the internal anterior thoracic nerve which enters it on its deep surface. Occasionally some fibres of the muscle take origin from the second rib.

The **subclavius** arises by a tendon prolonged for a little distance on the under surface of the muscle from the cartilage of the first rib. The

narrow muscular belly extends outwards along the groove on the under surface of the clavicle, and, becoming pointed at its end, is inserted at the extremity of the groove between the conoid and trapezoid ligaments. The great vessels and nerves passing between the neck and the axilla lie behind the muscle. It is supplied by a special nerve from the front of the union of the fifth and sixth cervical nerves in the brachial plexus.

MUSCLES OF THE SHOULDER.

These are the deltoid, the supraspinatus, the infraspinatus, the subscapularis, the teres minor, and the teres major.

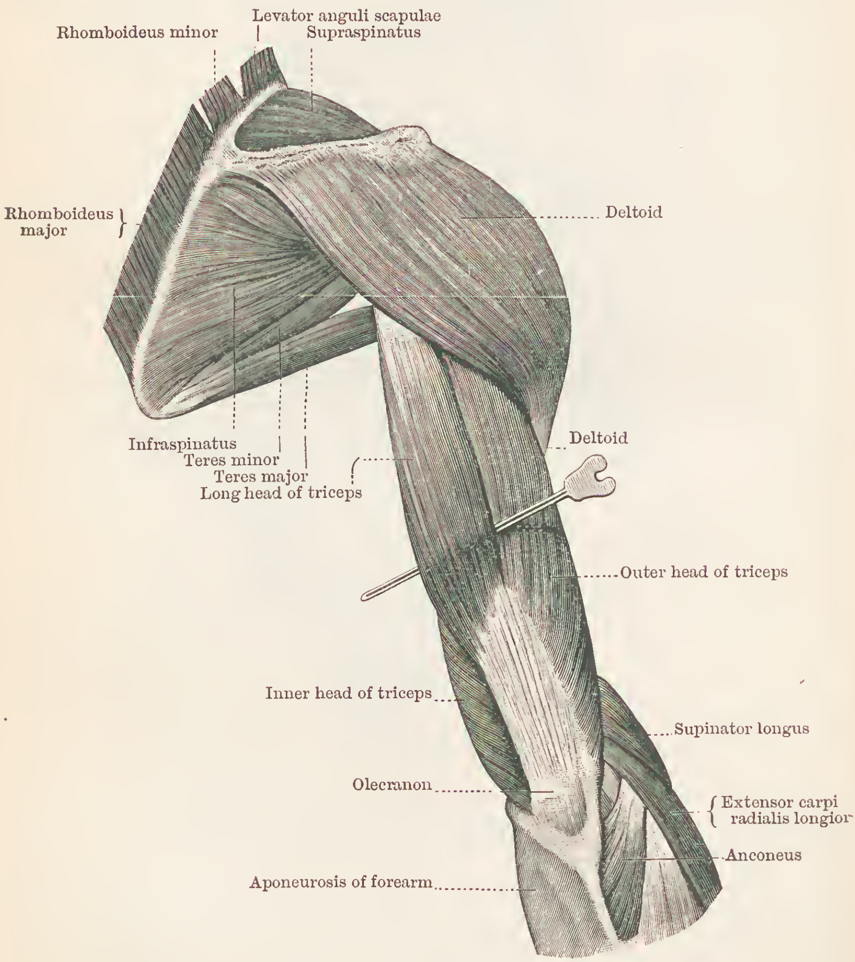


FIG. 233.—MUSCLES OF SHOULDER AND ARM, posterior view. (L. Testut.)

The **deltoid** arises (*a*) from the lower border of the spine of the scapula, (*b*) from the outer border of the acromion, and (*c*) from the anterior

border of the outer third of the clavicle. It is inserted into a rough area on the outer surface of the humerus, a little above the middle of the bone. It is triangular in outline. The clavicular and spinal portions, springing by short tendinous fibres, and, passing downwards as the anterior and posterior portions respectively of the muscle, are comparatively thin. The central portion of the muscle is thick, and contains in its substance some seven or eight tendinous septa which are prolonged for some distance downwards from the origin and upwards from the insertion, and are arranged in such a manner that those from above alternate in position with those from below; the muscular fibres are for the most part short, and pass obliquely either from the bony origin to the septa, or from the upper to the lower septa, or from the septa to the bony insertion. The insertion is partly tendinous, partly muscular; fibres are prolonged from it to the external intermuscular septum of the arm.

The deltoid lies on the upper and outer aspects of the shoulder, and covers the joint and the muscles inserted around it. Its anterior border is in contact with the pectoralis major. The subacromial bursa projects outwards beneath its origin. It is supplied by the circumflex nerve.

The **supraspinatus**, occupying the supraspinous fossa of the scapula, takes origin by fleshy fibres which spring from the area of the bone between the vertebral border and the neck, and from the investing aponeurosis. It passes outwards underneath the acromion and narrows to a tendon, which, after crossing the shoulder-joint and adhering to its capsule, is inserted into the highest of the three facets on the great tuberosity of the humerus. It is supplied by the suprascapular nerve.

The **infraspinatus** arises (*a*) from the infraspinous region of the scapula, with the exception of the area at the lower angle and outer border, from which the teres muscles spring, (*b*) from the under surface of the spine, and (*c*) from the investing aponeurosis. Narrowing as it passes upwards and outwards, it is inserted by a tendon into the middle facet of the great tuberosity of the humerus. The tendon is at first concealed within the muscular substance, and afterwards, in crossing the shoulder-joint, adheres intimately to the capsule. The muscle is to a great extent superficial, being only partly covered by the deltoid. It is supplied by the suprascapular nerve.

The **subscapularis** arises from the whole of the ventral surface of the scapula, with the exception of the region of the neck and of the area at the vertebral border to which the serratus magnus is attached. Many of the fibres spring directly from the bone, but in addition a number take origin from two or three tendinous laminae, which are prolonged into the substance of the muscle from the ridges of the venter. The muscle passes outwards, the lower fibres ascending considerably, the upper descending a little; it is inserted by a strong flat tendon into the small tuberosity of the humerus. The tendon crosses in front of the

capsule of the shoulder-joint, and adheres to it below, but is separated from it above by a bursa which usually communicates through an opening in the capsule with the cavity of the joint. Another bursa lies upon the anterior surface of the tendon, separating it from the common tendon of the biceps and coraco-brachialis muscles, which descends in front of it. The nerves of supply are the first and third subscapulars from the brachial plexus. The subscapularis takes part along with the latissimus dorsi and teres major in forming the posterior wall of the axilla.

The **teres minor** arises from the narrow area of the dorsal surface and the axillary margin of the scapula between the teres major and the long head of the triceps. It is inserted by a tendon into the lowest facet on

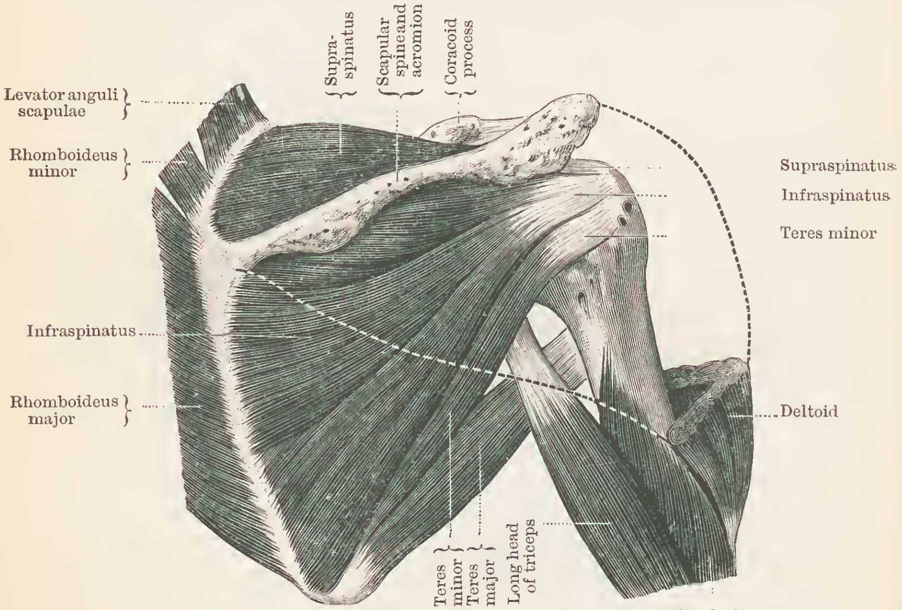


FIG. 234.—MUSCLES OF SHOULDER, posterior view. (L. Testut.)

the great tuberosity of the humerus, and by muscular fibres into the shaft for a little distance below. The muscle passes behind the long head of the triceps, and crosses the shoulder-joint, its tendon adhering to the capsule. It is supplied by the circumflex nerve.

The **teres major** arises from the rough area of the dorsal surface of the scapula adjacent to the lower third of the axillary border. It passes outwards in front of the long head of the triceps, and is inserted by a tendon into the posterior lip of the bicipital groove of the humerus. The tendon extends a little further down the bone than does that of the latissimus dorsi, which is inserted in front of it, and with which it is for some distance in close contact. It is supplied by the third subscapular nerve.

A triangular space is left between the upper border of the teres major, the margin of the scapula, and the upper end of the humerus; this space the long head of the triceps divides into two portions, the outer quadrilateral, the inner triangular.

THE MUSCLES OF THE ARM.

These are the coraco-brachialis, the biceps, the brachialis anticus, and the triceps. The first three occupy the front of the arm; the triceps with which the anconeus muscle is associated covers the posterior surface of the humerus.

The **coraco-brachialis** arises from the tip of the coracoid process of the scapula in association with the short head of the biceps. It is inserted into the inner surface of the shaft of the humerus about the middle of the bone. From the insertion some tendinous fibres are continued into the internal intermuscular septum of the arm. In the upper half of its length the muscle is conjoined with the short head of the biceps. It is pierced by the musculo-cutaneous nerve which supplies it, and is crossed near its insertion by the brachial artery.

The **biceps** (*biceps brachii*) arises from the scapula by two heads—the *long* from the tubercle above the apex of the glenoid fossa, the *short* from the tip of the coracoid process in association with the coraco-brachialis muscle. It is inserted into the posterior portion of the bicipital tuberosity of the radius, and by a slip into the fascia of the upper and inner part of the forearm.

The long head is a rounded tendon continuous at the margins of its origin with the glenoid ligament, and prolonged through the joint, where it is invested by the synovial membrane, to the bicipital groove of the humerus, down which it is continued for some distance. The short head, tendinous at first, soon becomes muscular, and separating from the coraco-brachialis in the upper third of the arm, blends a little further down with the muscular fibres of the long head to form the belly of the muscle, which occupies a prominent position on the front of the arm. The tendon of insertion, originating a little above the elbow, passes deeply into the hollow below the joint to reach the bone, a bursa intervening between it and the most prominent portion of the tuberosity. From its inner edge about the level of the joint an aponeurotic slip, the *semilunar fascia*, is detached and becomes incorporated with the fascia of the inner region of the forearm.

The pectoralis major crosses the heads of the muscle. The brachialis anticus lies behind it in the lower part of the arm. The brachial artery lies along its inner edge, and is often overlapped by it. The semilunar fascia crosses the artery. The biceps is supplied by the musculo-cutaneous nerve which lies behind it. Occasionally a third head, springing from the humerus close to the insertion of the coraco-brachialis, is met with;

when present, it is usually continued into the semilunar fascia. A fourth head has been noted in some instances.

The **brachialis anticus** (*brachialis*) springs by fleshy fibres from the lower portion of the anterior surface of the humerus, from the anterior surface of the internal intermuscular septum, and from the upper end

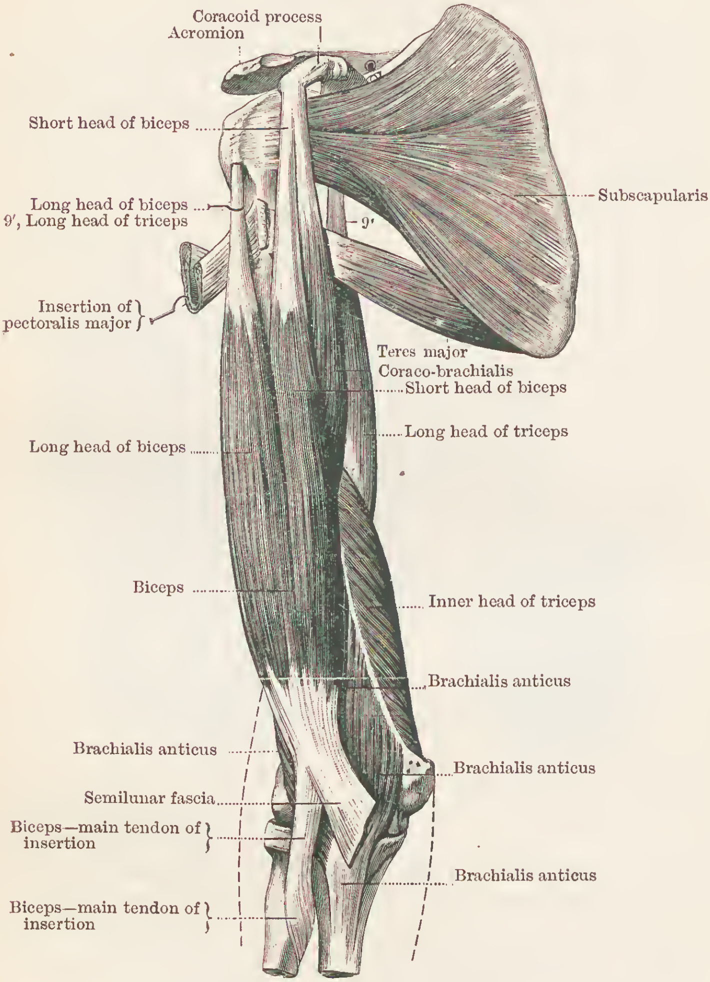


FIG. 235.—MUSCLES OF THE FRONT OF THE ARM. (L. Testut.)

of the external septum. It is inserted by a thick tendon into the base of the coronoid process of the ulna. At its origin the muscle clasps the insertion of the deltoid above, and extends below nearly as far as the place of attachment of the capsular membrane of the elbow-joint. From the greater part of the external septum it is separated by the supinator longus and the extensor carpi radialis longior. The musculo-cutaneous

nerve lies on its surface and supplies it. It receives also a small branch from the musculo-spiral nerve, which passes down between it and the two last-named muscles. The brachial vessels and median nerve lie upon the surface of the muscle.

The **triceps** (*triceps brachii*) occupies the back of the arm. It arises

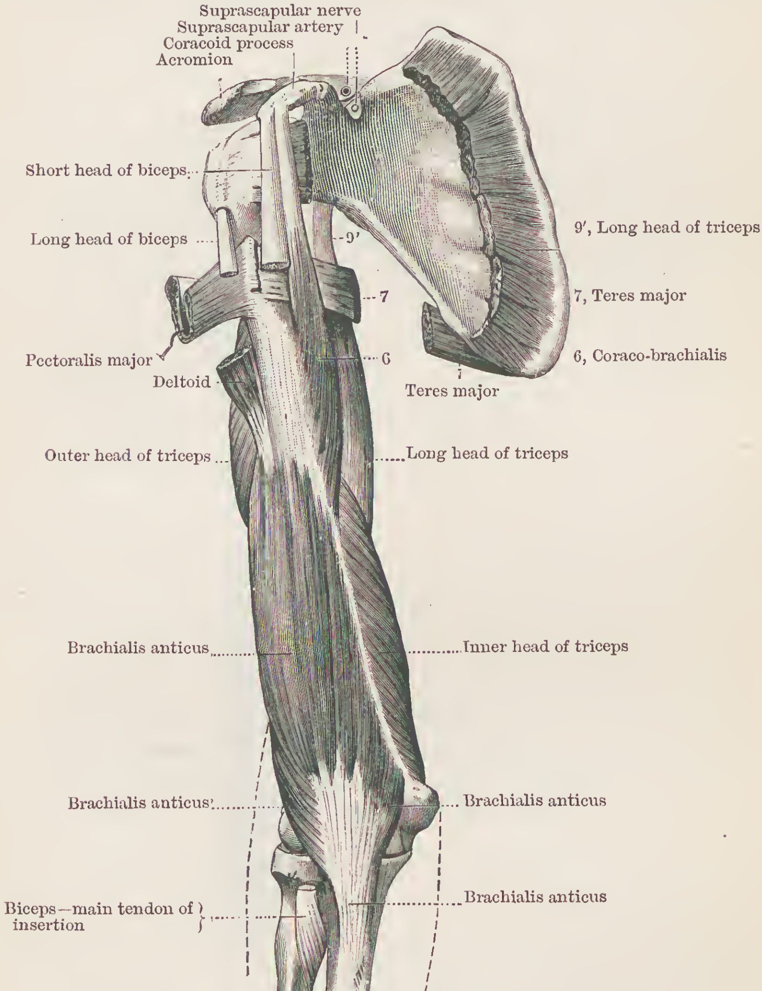


FIG. 236.—MUSCLES OF THE FRONT OF THE ARM, deep layer. (L. Testut.)

by three heads—the *long*, the *external*, and the *internal*. The *long* head springs by a short tendon of about an inch or an inch and a half in breadth from the axillary border of the scapula immediately below the glenoid fossa; the *external* head springs by short tendinous fibres from the posterior surface of the humerus along a narrow line, extending from the insertion of the teres minor down to the margin of the musculo-

spiral groove, and by a few fibres from the upper extremity of the external intermuscular septum. The *internal* head, narrow and pointed above, but covering the whole breadth of the bone below, arises by fleshy fibres from the posterior surface of the humerus internal to and below the musculo-spiral groove, and from the posterior surfaces of both the intermuscular septa, the origin extending from the insertion of the

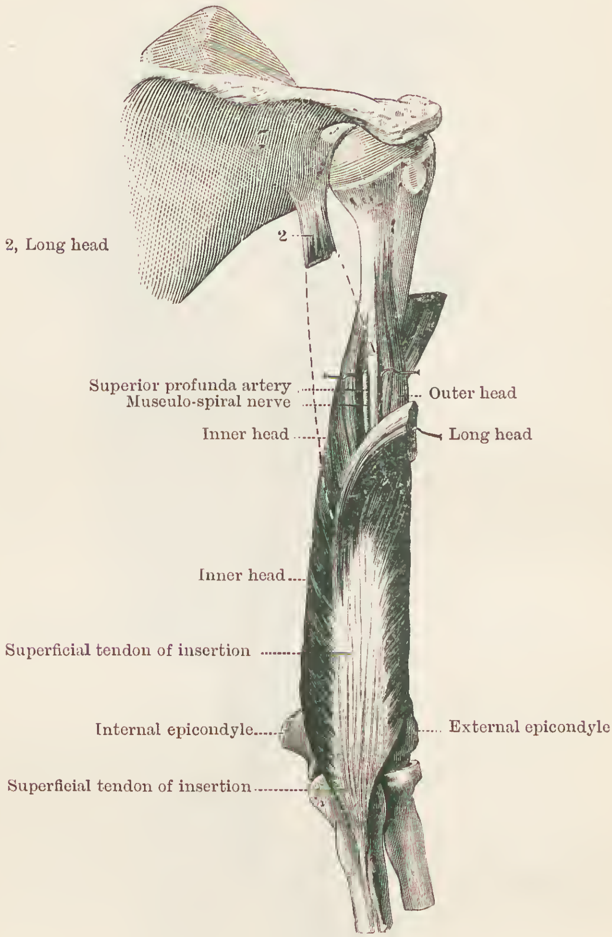


Fig. 237.—Triceps. (L. Testut.)

teres major to within a short distance of the olecranon fossa. The muscle is inserted into the upper surface of the olecranon process of the ulna in two planes, superficial and deep. The fibres descending from the long head form a flat superficial tendon, which is joined on its outer side by the fibres from the outer head, and on its inner side by a few of the most internal fibres of the inner head, and is inserted into an area close to the posterior margin of the upper surface of the

olecranon process; this tendon is continuous at its margins with the fascia of the forearm. The remaining fibres of the muscle coming from the inner head pass, some to the deep surface of the superficial tendon, and some directly to the upper surface of the olecranon, where they are inserted close to the place of attachment of the capsular ligament. Some of the deepest fibres are attached to the capsule and receive the name of *subanconeus.* The lower fibres of the outer portion of the inner head lie from origin to insertion side by side with the higher fibres of the anconeus. A narrow area of bone intervenes between the deep and superficial insertion into the olecranon, and the space is usually occupied by a small bursa. The muscle is supplied by the musculo-spiral nerve, which, along with the superior profunda artery, descends between the outer and inner heads in the musculo-spiral groove.

The **anconeus,** a small triangular muscle, arises by tendinous and fleshy fibres from the posterior surface of the external epicondyle of the humerus. It is inserted into a rough line on the outer surface of the olecranon process and into the outer edge of the posterior border of the ulna, extending in many cases nearly a third of the length of the bone. The uppermost fibres of origin are very short, and lie in serial continuity with those of the lower and outer part of the inner head of the triceps, from which at times they are not easily distinguished. Neither is the muscle distinguishable from the humeral heads of the triceps in function. Moreover, it is supplied by a branch of the musculo-spiral nerve, which arises from the main trunk above the middle of the humerus, and traverses the deep part of the triceps. There is therefore much to be said for looking on this muscle as a part of the triceps.

Actions of the Muscles of the Shoulder and Arm.

In considering the special agencies which produce the various movements of the arm upon the body, it must be borne in mind that the shoulder-girdle is only directly articulated with the trunk at the sterno-clavicular joint, and that it receives its chief support from the surrounding muscles, notably the trapezius and the levator anguli scapulae. The movements at the scapulo-humeral articulation are very free and are permitted in all directions, their limits being set partly by the ligaments of the joint, and partly by the tension of the surrounding muscles; but all movements at the joint are accompanied to a greater or less extent by movements of the scapula upon the chest wall. As an example, when the arm is being raised from the side, in addition to the movement at the scapulo-humeral articulation, simultaneous movements of both shoulder blade and collar bone take place, the scapula rotating in such a manner that the lower angle passes forwards and upwards, the upper being correspondingly depressed and drawn backwards, while the outer end of the clavicle is pulled backwards and somewhat tilted so that the anterior edge is turned upwards.

The *trapezius* rotates the scapula and clavicle in the manner above described, and powerfully assists the deltoid in raising the arm. The *levator anguli scapulae* and *rhomboidei* raise the upper angle of the shoulder blade, and draw the base towards the spines, and thus oppose the action of the trapezius. The *serratus magnus* draws the scapula from the spines and comes into play in throwing the arm forwards and in pushing. The *latissimus dorsi* depresses the raised arm, draws the humerus backwards, and rotates it inwards; its action is well illustrated by the backward sweep of the arm in swimming. The *pectoralis major* draws the arm forwards, and assists in depressing the raised arm. The *pectoralis minor* draws the coracoid process forwards, and opposes the rotating action of trapezius. The *subclavius*, acting upon the outer end of the clavicle, also opposes the rotating action of the trapezius. The greater part of the *deltoid* abducts the humerus; but the posterior fibres, those which spring from the scapular spine, would rather tend to draw the humerus downwards and backwards. The *teres major*, like the latissimus dorsi, draws downwards and backwards and rotates inwards. The *subscapularis* rotates inwards, and may assist in depressing. The *teres minor* rotates outwards, and may also have a slight depressing action. The *infraspinatus* rotates outwards, and the *supraspinatus* assists the deltoid in abducting. The *biceps*, when acting on the shoulder alone, and the *coraco-brachialis* assist in abducting, and the latter muscle and the short head of the biceps also draw the limb slightly forwards. The long head of the triceps, when the elbow joint is fixed, assists in depressing the raised arm.

In addition to the actions already described, many of the muscles have an important action upon the trunk if the limb be fixed: thus the latissimus dorsi and pectoralis major, and the muscles which in ordinary circumstances depress the raised arm draw the body upwards on the arms in climbing; and the pectoralis major and minor, the latter especially, and perhaps also the lower fibres of the serratus magnus, by elevating the ribs take part in the motions of forced inspiration.

The long head of the *triceps* depresses the arm, and extends the forearm; the rest of the muscle simply extends the forearm; the anconeus acts along with the inner head. The *biceps* supinates and flexes the forearm, and assists to raise the arm. The short head of the muscle, along with the *coraco-brachialis*, while assisting to raise the arm, also draws it forward. The *brachialis anticus* flexes the forearm.

The Axilla.

The **axilla** is the pyramidal space which lies between the upper end of the humerus and the chest wall, and is bounded in front and behind by the muscles which pass from the trunk to the upper limb. The *anterior wall* is formed by the pectoralis major, on the deep surface of which lie the costo-coracoid membrane and the pectoralis minor. The *posterior wall* is formed by the subscapularis, teres major, and latissimus dorsi.

The anterior and posterior walls come nearly into contact at the bicipital groove of the humerus, but have lying between them the biceps and coraco-brachialis, which may be considered as forming a narrow *outer wall*, against which rest the axillary vessels, with the trunks of the brachial plexus of nerves. The *inner wall* is covered by the serratus magnus. The *apex* is bounded by the clavicle, the upper margin of the scapula, and the outer margin of the first rib. The *base* is covered by the axillary fascia.

Deep Fascia of the Shoulder and Arm.

Fascia of the front of the shoulder. A somewhat thin layer of fascia covers the anterior surface of the pectoralis major. It is attached above to the clavicle and internally to the sternum: below, it is continuous with the abdominal fascia; externally it passes into the fascia covering the deltoid and into the axillary fascia.

Fascia of the back of the shoulder. A strong layer of aponeurosis covers the infraspinatus and teres minor, where they are left uncovered by the deltoid. It has attachments to the spine and the vertebral and axillary margins of the scapula, and is continuous posteriorly with the fascia covering the trapezius, rhomboidei and latissimus dorsi. At the hinder margin of the deltoid it splits; one portion passes superficial to the muscle, and becomes continuous with the fascia covering the pectoralis major; the other invests the muscles on the deep surface of the deltoid. The fascia is continuous in front and below with the axillary fascia and the fascia of the arm. Muscular fibres of the suspraspinatus and infra-spinatus muscles spring from its deep surface, and the deltoid tendon at its posterior border is partially blended with it.

The **axillary fascia** is the name given to the strong layer which, stretching between the anterior and posterior borders, forms the floor of the axillary space. It is continuous below with the fascia of the arm, in front with that covering the pectoralis major, and behind with that of the latissimus dorsi and teres muscles. On the deep aspect of the pectoralis major a strong layer of fascia, the *costo-coracoid membrane*, stretches from the first rib at its sternal end to the coracoid process (Fig. 152, *h*); at its upper border it embraces the subclavian muscle, and is fixed to the clavicle; below, it surrounds the pectoralis minor and joins the fascia stretched across the base of the axilla, binding it down, so that when the arm is raised the axilla has its greatest depression towards the front. The costo-coracoid membrane is pierced by the cephalic vein and by branches of artery and nerve supplying the pectoralis major.

The **deep fascia of the arm**, for the most part thin, but becoming stronger in the neighbourhood of the epicondyles, completely surrounds the muscles. At the inner edge of the biceps, near the middle of the arm, an opening transmits the basilic vein aud internal cutaneous nerve. Two well-marked intermuscular septa separate the muscles of the front from the triceps behind, and afford origin from both surfaces to muscular fibres.

The **internal intermuscular septum** extends from the insertion of the coraco-brachialis muscle, from which it receives fibres, to the internal epicondyle. It is pierced by the inferior profunda and anastomotic arteries, and by the ulnar nerve and a branch of the musculo-spiral nerve.

The **external septum**, not so strong as the internal, stretches from the insertion of the deltoid, from which it receives fibres, along the outer ridge to the external epicondyle. It is pierced by the anterior division of the superior profunda artery and by the musculo-spiral nerve.

MUSCLES OF THE FOREARM.

The muscles of the forearm are arranged in four groups, two of them superficial in position, the other two deeply placed. Of the superficial groups the inner springs from the internal epicondyle of the humerus and spreads downwards and outwards over the front of the forearm, and the muscles belonging to it, which enter the hand, pass in front of the anterior surface of the wrist; the outer springs from the external epicondyle, and the muscles belonging to it, which reach the hand, cross the posterior surface of the wrist joint. The hollow of the elbow is a triangular space of variable size placed in front of the elbow-joint; its apex is directed downwards and slightly outwards; it is bounded on each side by the marginal muscle of the inner and outer groups respectively. The deep groups of muscles belong respectively to the anterior and posterior surfaces of the forearm.

Anterior and Inner Superficial Group.

This group is formed of five muscles. From without inwards they are the pronator radii teres, flexor carpi radialis, palmaris longus, flexor digitorum sublimis, and flexor carpi ulnaris. They are very closely associated together at their origin from the internal epicondyle from which they spring in the order named, and in addition each receives fibres from the investing fascia of the forearm and from intermuscular septa which pass between and separate from one another the individual muscles at their upper ends. Besides the origins already mentioned three of the five muscles present additional slips or heads. The pronator teres receives a slip from the coronoid process, the flexor carpi ulnaris is connected with the olecranon process, and the flexor digitorum sublimis has its main head of origin from the humerus, continued downwards upon the internal lateral ligament and the coronoid process, and receives in addition a thin broad slip from the oblique line and anterior border of the radius.

The **pronator radii teres** (*pronator teres*) springs from the internal epicondyle, the fascia of the forearm and an intermuscular septum on its inner side; and it receives an additional slip from the inner side of the coronoid process. The muscle is somewhat rounded in outline, and is

directed downwards and outwards. It is inserted under cover of the supinator longus into a rough impression on the outer surface of the radius at the lower extremity of the oblique line. The median nerve

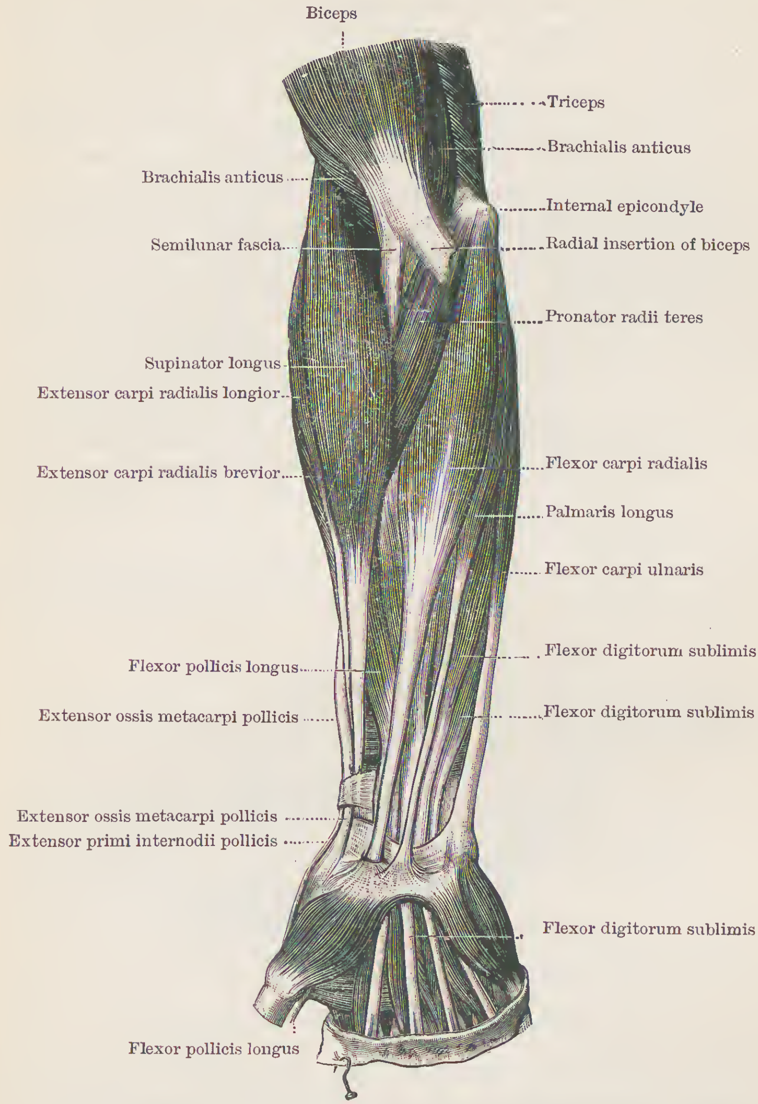


FIG. 238.—MUSCLES OF THE FRONT OF THE FOREARM, superficial layer. (L. Testut.)

descends between the heads of origin, and the ulnar artery passes downwards and inwards behind the deep head.

The **flexor carpi radialis** springs from the internal epicondyle, the fascia of the forearm and the intermuscular septa on both sides. It is inserted into the anterior surfaces of the second and third metacarpal

bones at their bases. The muscular belly narrows about the middle of the forearm, and gives place to a long tendon which, in its passage downwards, occupies a special compartment in the outer part of the anterior annular ligament and passes in front of the scaphoid and along the groove of the trapezium. A synovial sheath surrounds the lower part of the tendon.

The **palmaris longus** springs from the internal epicondyle, the fascia of thc forearm and the intermuscular septa on both sides. It narrows in the upper third of the arm to a slender tendon which passes in front of the anterior annular ligament to end in the palmar aponeurosis.

The **flexor carpi ulnaris** springs from the internal epicondyle, the fascia of the forearm and the intermuscular septum on its outer side; fibres also spring from the inner side of the olecranon process, and continuously therewith in the upper three-fourths of the forearm from the strong layer of fascia attached to the posterior border of the ulna. It is inserted into the pisiform bone from which, however, the tendon is continued onwards in the form of slips which attach themselves to the anterior annular ligament, the unciform process and the bases of the fourth and fifth metacarpal bones. The muscular fibres give place to tendon in the lower fourth of the forearm. The ulnar nerve enters the forearm between the heads of the muscle.

The **flexor digitorum sublimis** springs from the internal epicondyle, the fascia of the forearm and the intermuscular septa on both sides; and

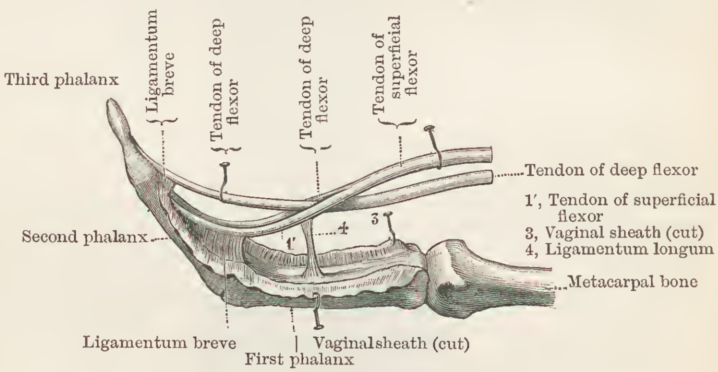


Fig. 239.—Flexor Tendons on Front of Finger. (L. Testut.)

more deeply placed fibres continuous with the humeral head spring from the internal lateral ligament of the elbow and from the side of the coronoid process; a second head, broad and thin, springs from the radius, extending in its origin downwards along the oblique line and a small part of the anterior border of the bone. It is inserted by four tendons into the anterior surfaces of the second phalanges of the four inner digits. The muscle breaks up about the middle of the forearm, and the tendons pass in pairs behind the anterior annular ligament, those for the

middle and ring fingers lying in front of those for the index and little fingers. Opposite the first phalanx each tendon splits into two portions, which embrace the tendon of the deep flexor, bending round it till the original borders meet and effect a junction behind it. Immediately before the insertion, which takes place into the borders of the anterior surface of the second phalanx, the tendon again splits into two portions. The tendons, along with those of the deep flexor, are surrounded by a synovial sheath as they pass behind the annular ligament.

Passing along the anterior surface of the phalanges the pair of tendons belonging to each finger is covered by an arch of strong fibrous tissue (*the vaginal ligament*) springing from the margins of the bones; opposite the joints the sheath is much reduced in thickness to allow of flexion, and is formed of a delicate membrane with diagonally-crossing fibres attached behind to the interphalangeal ligaments. At the third phalanx the sheath is much reduced and forms a thin covering to the tendon of the deep flexor.

This long canal is lined by a synovial membrane which is reflected over the tendons so as to surround each, but little bands of membrane (*vincula tendinum*) pass from one tendon to another, and from the tendons to the bones. The vincula are of two kinds; each tendon close to its termination is attached to the phalanx above that into which it is inserted by a considerable band, *the ligamentum breve*; other more delicate and less constant connections are termed *ligamenta longa*.

Deep Anterior Group.

The muscles of this group are three in number—the flexor digitorum profundus, flexor pollicis longus, and pronator quadratus. They are closely applied to the anterior surface of the bones of the forearm.

The **pronator quadratus**, a flat four-sided muscle, arises from the anterior surface of the lower fourth of the ulna, and is inserted into the anterior surface and inner border of the corresponding portion of the radius. The other two deep muscles descend in front of it.

The **flexor digitorum profundus**, embracing the coronoid process above and extending in its origin as far as the margin of the pronator quadratus below, arises from the anterior and inner surfaces of the upper three-fourths of the shaft of the ulna, the ulnar half of the corresponding region of the interosseous membrane, and, on the inner side, from the aponeurosis attached to the posterior border of the ulna. It passes to the four inner fingers, and is inserted in each case into the anterior surface of the terminal phalanx at its base. The tendons lie side by side as they pass behind the anterior annular ligament, and only become distinctly separate from one another when they reach the palm. Along with those of the superficial flexor which lie in front of them, they are at the wrist surrounded by a synovial sheath. In the palm they give origin

to the lumbricales muscles. In each finger the tendon is invested by the fibrous and synovial sheaths already described, and pierces opposite the first phalanx the tendon of the superficial flexor. The ligamentum breve, which unites the tendon to the second phalanx, is specially strengthened by elastic tissue.

FIG. 240.—MUSCLES OF FRONT OF FOREARM, deep layer. (L. Testut.)

The **lumbricales** (Fig. 244), four small rounded muscular bellies tapering to delicate tendons, spring, a little below the annular ligament, from the surfaces and the outer edges of the tendons of the deep flexor; the two inner muscles, however, spring likewise from the inner edges of the adjacent tendons. They pass to the four inner fingers, where each is inserted into the fibrous expansion of the extensor tendons on the back of the first phalanx. The tendons cross the outer surfaces of the heads of the metacarpal bones.

The **flexor pollicis longus**, extending in its origin from the bicipital tuberosity to the margin of the pronator quadratus, and narrow and pointed above where it is limited by the oblique line, springs from the anterior surface of the radius and the radial half of the adjacent interosseous membrane; in many cases a delicate slip from the coronoid process joins the inner edge of the muscle. It is inserted into the anterior surface of the terminal phalanx of the thumb at its base. The tendon passes behind the anterior annular ligament and between the outer and inner portions of the short flexor of the thumb to gain the anterior surface of the phalanges, to which it is bound down by a vaginal sheath similar to those of the other digits. From the wrist to the insertion it is surrounded by a synovial sheath.

Nerve supply of the muscles of the front of the forearm. These muscles are supplied by the median and ulnar nerves, the ulnar contributing branches to the flexor carpi ulnaris and the inner half of the flexor profundus digitorum, the median to the others. The two outer lumbricales are supplied by the median, the two inner by the ulnar.

Synovial sheaths. A large synovial sheath surrounds the tendons of the superficial and deep flexors of the fingers, and the median nerve, as they pass behind the annular ligament. It extends upwards for a little distance above the ligament and downwards into the metacarpal region of the hand, where it terminates by four blind extremities. It is subject to considerable variations. Frequently in the case of the little finger and occasionally in the others, it passes downwards on the tendons to join the digital sheaths. It often communicates with the sheath of the flexor pollicis longus. On the other hand it is sometimes found completely or partially divided by a partition into lateral portions. The tendon of the flexor pollicis longus is inclosed in a special sheath, which is nearly always continuous with its digital sheath. The tendon of the flexor carpi radialis is likewise inclosed in a special sheath.

Posterior and Outer Superficial Group.

The muscles of this group in order from before backwards are—the supinator longus, extensor carpi radialis longior, extensor carpi radialis brevior, extensor digitorum communis, extensor minimi digiti, and extensor carpi ulnaris. The first two spring from the external supracondylar ridge of the humerus and from the anterior surface of the external intermuscular septum of the arm; the others, in the order named, arise from the external epicondyle by a common tendon, and receive fibres from the fascia of the forearm and the intermuscular septa derived from it.

The **supinator longus** (*brachio-radialis*) arises from the upper two-thirds of the external supracondylar ridge of the humerus and the corresponding area of the external intermuscular septum of the arm. It is inserted into the outer border of the radius immediately above the styloid process.

The fleshy belly of the muscle narrows to a tendon in the lower half of the forearm.

The **extensor carpi radialis longior** arises from the lower third of the

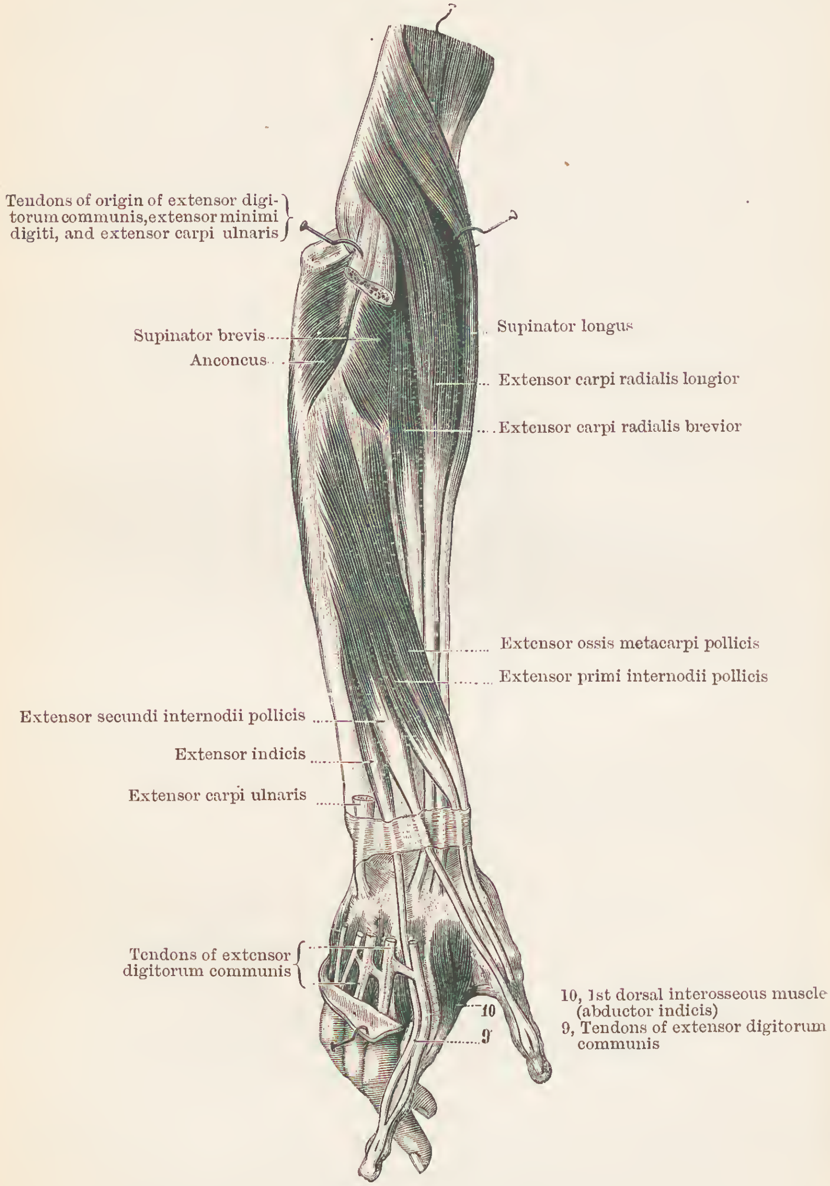


FIG. 241.—MUSCLES OF BACK OF FOREARM, deep layer. (L. Testut.)

external supracondylar ridge of the humerus and the corresponding area of the external intermuscular septum of the arm. It is inserted into the posterior surface of the base of the second metacarpal bone.

The **extensor carpi radialis brevior** springs from the external epicondyle by the common tendon, and receives fibres from the fascia of the forearm and the intermuscular septa. It is inserted into the posterior

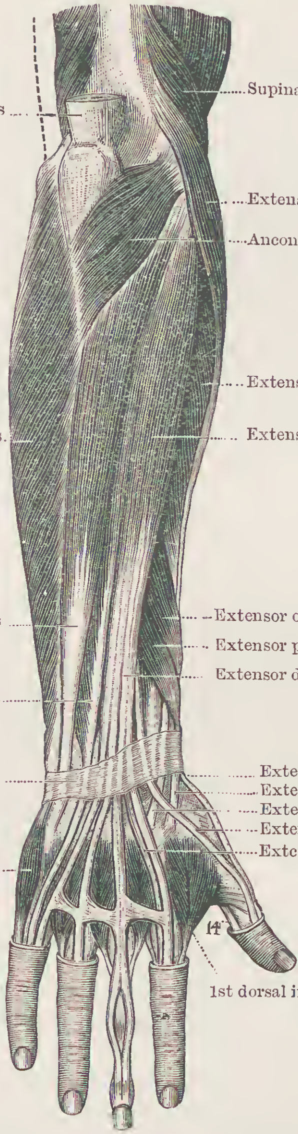


Fig. 242.—Muscles of Back of Forearm, superficial layer. (L. Testut.)

surface of the base of the third metacarpal bone. The two radial extensors become tendinous about the middle of the forearm, and their tendons are, a little lower down, crossed superficially by the tendons of the extensors of the metacarpal bone and first phalanx respectively of the thumb, a

bursa being interposed at the point of crossing. Thereafter the two tendons, under cover of the posterior annular ligament, pass along the outermost broad groove on the back of the radius, where each is surrounded by a synovial sheath. At the insertion a small bursa is interposed between each tendon and the bone.

The **extensor digitorum communis** springs by the common tendon from the external epicondyle, and receives fibres from the fascia of the forearm and the intermuscular septa. It is inserted into the posterior surfaces of the second and third phalanges of the four inner digits. The tendons separate from one another a little above the annular ligament, and pass side by side along the inner broad groove on the back of the radius, receiving a synovial investment. On the dorsum of the hand the diverging tendons present two connections of different kinds with one another; the more obvious consists of two slips given off from the tendon of the ring finger to join the tendons of the middle and little finger, and is well known to musicians; the other consists of a transparent transverse band between the tendons of the middle finger and forefinger. On the back of the *first phalanx* of each finger the tendon spreads out into a fibrous expansion, which covers the bone posteriorly. The expansion is continued below into three thin slips, the median of which is attached to the base of the *second phalanx*, while the two lateral, after joining with one another, reach the base of the *third phalanx*. The tendinous expansions on the backs of the first phalanges are joined by the tendons of the lumbricales and interosseous muscles, and detach from their margins fibres to the metacarpo-phalangeal and interphalangeal ligaments. In the case of the index, and in that of the little finger, the expansion receives in addition an accession from the tendon of the special extensor of the digit.

The **extensor minimi digiti** (*extensor digiti quinti proprius*), a long slender muscle, springs by the common tendon from the external epicondyle, and receives fibres from the fascia of the forearm and the intermuscular septa. The tendon passes along a groove between the lower ends of the radius and ulna, and on the back of the hand divides into two, one portion joining the innermost tendon of the common extensor, the other passing directly to the fibrous expansion on the back of the first phalanx of the little finger.

The **extensor carpi ulnaris** springs by the common tendon from the external epicondyle of the humerus, and receives fibres from the fascia of the forearm and the intermuscular septa. It is inserted into the tuberosity at the base of the fifth metacarpal bone. The muscle descends along the inner portion of the posterior surface of the ulna, and the tendon, surrounded by a synovial sheath which is continued almost to the insertion, passes along a special groove on the posterior surface of the lower extremity of the bone.

The Deep Posterior Group.

There are five muscles in this layer: the supinator brevis, extensor ossis metacarpi pollicis, extensor primi internodii pollicis, extensor secundi internodii pollicis, and extensor indicis. They lie close to the bones and the interosseous membrane, and are placed from above downwards in the order in which they are named above. The inner limit of their origin is marked by a line upon the ulna, which begins above on the outer surface of the head at the hinder edge of the lesser sigmoid cavity, and is continued down the middle of the posterior surface of the shaft, dividing it into inner and outer portions. The upper fifth of this line marks the limit of the ulnar origin of the supinator brevis, the second fifth that of the extensor of the metacarpal bone of the thumb; the third and fourth fifths correspond to the position of the extensors of the second phalanx of the thumb and of the index finger. From the lower fifth no muscular fibres spring. The extensor of the first phalanx of the thumb lies at its origin from the interosseous membrane between the extensor of the metacarpal bone and that of the second phalanx and does not extend so far inwards as the ulna. The muscles are directed downwards and outwards.

The **supinator brevis** (*musculus supinator*) arises from the orbicular ligament of the radius, the external lateral ligament of the elbow, the depression beneath the lesser sigmoid cavity of the ulna and the ridge limiting the depression behind. It is inserted into the outer surface of

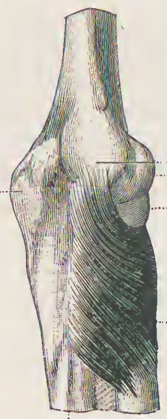


Fig. 243.—Supinator Brevis. (L. Testut.)

the radius, extending as far forwards as the oblique line. The muscle is flat and four-sided, narrow above and at its origin, broad below and at its insertion. The posterior interosseous nerve runs in its substance.

The **extensor ossis metacarpi pollicis** (*abductor pollicis longus*) arises from the outer part of the posterior surface of the ulna below the

supinator brevis and above the middle of the bone, from the adjacent interosseous membrane, and from a small area of the posterior surface of the radius behind and below the insertion of the pronator teres. It is inserted into the base of the metacarpal bone of the thumb on its outer side. Its tendon along with that of the extensor of the first phalanx crosses the tendons of the radial extensors of the carpus, a bursa being interposed, and passes along the groove on the outer surface of the lower end of the radius. A common synovial sheath surrounds both tendons in the groove.

The **extensor primi internodii pollicis** (*extensor pollicis brevis*) arises below the extensor of the metacarpal bone, from the interosseous membrane and the posterior surface of the radius. It is inserted into the posterior surface of the base of the first phalanx of the thumb. Its tendon accompanies that of the extensor of the metacarpal bone.

The **extensor secundi internodii pollicis** (*extensor pollicis longus*) arises from the outer portion of the posterior surface of the ulna occupying an area placed about the middle of the bone, and from the adjacent interosseous membrane. It is inserted into the posterior surface of the base of the terminal phalanx of the thumb. Its tendon passes along the narrow oblique groove on the back of the radius and crosses the radial artery on the back of the carpus. In the groove the tendon is surrounded by a synovial bursa.

The **extensor indicis** (*extensor indicis proprius*) arises from the outer portion of the posterior surface of the ulna below the middle of the bone, and by a few fibres from the adjacent interosseous membrane. Its tendon passes with those of the common extensor, and terminates in the expansion on the back of the first phalanx of the index finger.

Nerve supply of the posterior and outer group of muscles. These muscles are, with the exception of the supinator longus and the extensor carpi radialis longior, which receive their twigs from the musculo-spiral, supplied by the posterior interosseous nerve.

Synovial sheaths of the extensor tendons. As they pass along the bony grooves into which they are bound by the posterior annular ligament these tendons are all surrounded by synovial sheaths. As a rule one common sheath surrounds all the tendons of each groove, but the radial extensors of the carpus are each inclosed in a separate synovial sheath.

Variations in the Forearm.

Many of the muscles are at times absent altogether, and, in the case of the larger muscles, individual tendons or heads of origin are often wanting. On the other hand, muscles are sometimes found double, or may have additional heads of origin or tendons of insertion. Frequently slips pass from one to another, and in some cases distinct additional muscles are found. As the number of recorded variations is very large, only the more

important need be briefly noticed. The humeral head of the pronator teres sometimes extends upwards along the supracondylar ridge for some distance, and when a supracondylar process is present the muscle is usually connected with it. The palmaris longus is absent in one out of every ten cases; it is often double; sometimes its muscular belly is found in the lower part of the forearm, the muscle springing by a narrow tendon. The flexor digitorum sublimis is sometimes absent, its place being taken by a short muscle which springs in the hand from the annular ligament and palmar aponeurosis; less important is the absence of its radial head, or the division of the muscle into four fleshy bellies. In connection with the deep flexor an accessory slip from the coronoid process to one or other of the tendons has been frequently observed. To the lower extremities of the radius and ulna respectively two small muscles, the radio-carpal and cubito-carpal, have occasionally been found attached; the first passes towards the trapezium and os magnum, the second to the unciform.

The radial extensors of the carpus frequently send a slip to the metacarpal bone or to one of the special muscles of the thumb. The tendon of insertion of the ulnar extensor of the carpus often sends on an expansion which reaches the back of the first phalanx of the little finger. From the upper part of the supinator brevis two small slips have been observed to pass to the orbicular ligament, reaching it, the one in front and the other behind, and acting as tensors of the ligament.

MUSCLES OF THE HAND.

The **palmaris brevis** consists of a few fleshy fibres springing from the inner edge of the palmar fascia and inserted into the skin on the inner border of the palm. It is very variable in size, and is sometimes absent altogether. It crosses superficially the ulnar artery and nerve.

Muscles connected with the Thumb.

The short muscles of the thumb form the *thenar eminence* of the hand.

The **abductor pollicis** (*abductor pollicis brevis*) arises from the outer part of the annular ligament and from the ridge of the trapezium. It is inserted into the outer border of the first phalanx of the thumb at its base.

The **opponens pollicis** springs from the outer part of the anterior annular ligament and the surface of the trapezium. It is inserted into the metacarpal bone of the thumb along the whole length of its outer border and the adjacent part of its anterior surface. The muscle lies behind the abductor.

The **flexor pollicis brevis** is formed of two portions—an outer which is also superficial at its origin, and an inner or deep portion. The outer

portion arises from the lower edge of the outer part of the anterior annular ligament, and is inserted by a short tendon which contains a sesamoid bone into the outer border of the first phalanx at its base. The inner portion arises by a broad origin from the ligaments and fibrous structures, covering the three outer bones of the second row of the carpus, and from the bases of the three outer metacarpals. Its most

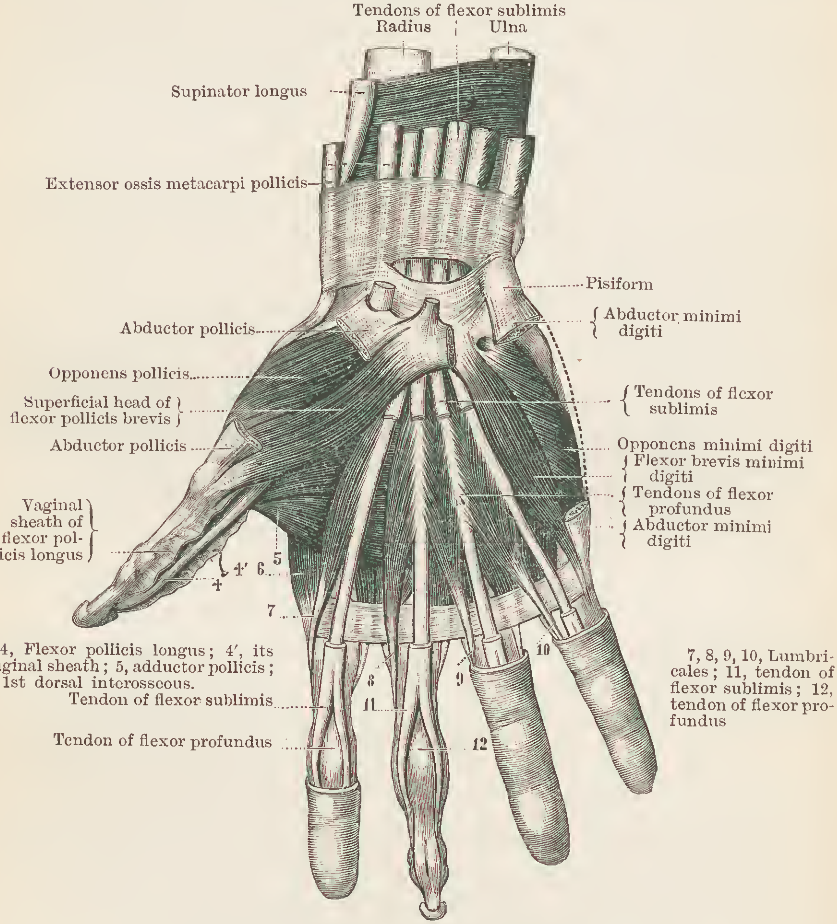


FIG. 244.—MUSCLES OF HAND, superficial layer. (L. Testut.)

superficial fibres, forming a rounded slip, pass obliquely behind the tendon of the long flexor to join the tendon of insertion of the outer head of the muscle. The deeper fibres are inserted along with the adductor into the inner border of the first phalanx at its base by a tendon which, like that of the outer portion of the muscle, contains a sesamoid bone.

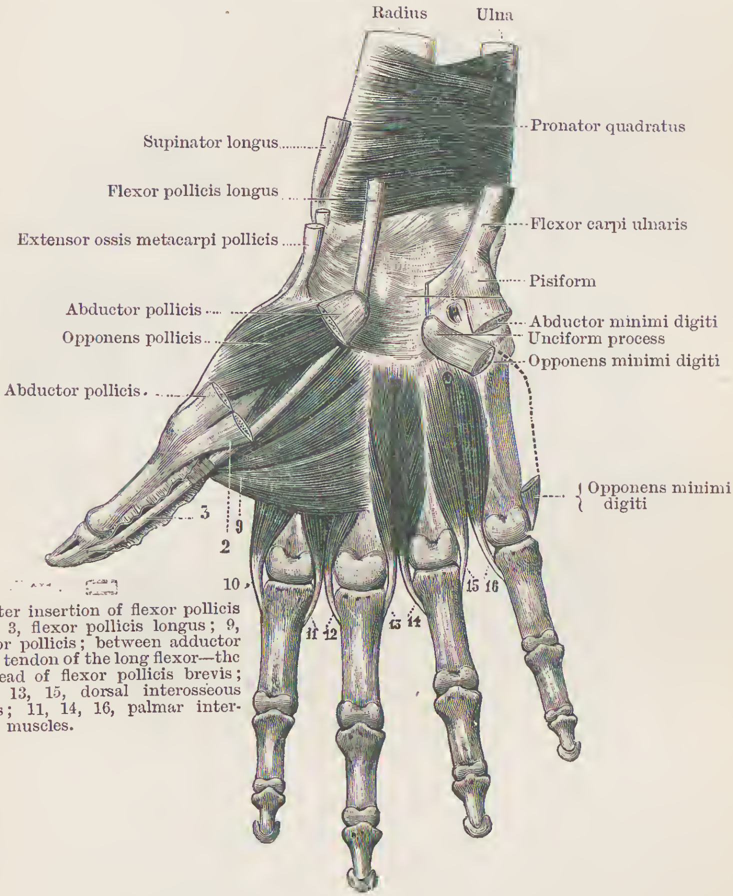
The **adductor pollicis**, triangular in outline, arises from the anterior

ridge of the metacarpal bone of the middle finger. It is inserted along with the deep portion of the flexor brevis.

Muscles connected with the Little Finger.

The short muscles of the little finger form the *hypothenar eminence.*

The **abductor minimi digiti** springs from the pisiform bone. It is



2, Outer insertion of flexor pollicis brevis; 3, flexor pollicis longus; 9, adductor pollicis; between adductor and the tendon of the long flexor—the deep head of flexor pollicis brevis; 10, 12, 13, 15, dorsal interosseous muscles; 11, 14, 16, palmar interosseous muscles.

Fig. 245.—Muscles of Hand, deep layer. (L. Testut.)

inserted into the inner border of the first phalanx of the little finger at its base.

The **flexor brevis minimi digiti** springs from the unciform process and the anterior annular ligament. It is inserted along with the abductor.

The **opponens minimi digiti** arises in common with the flexor brevis. It is inserted into the anterior border and inner surface of the metacarpal bone of the little finger.

The Interosseous Muscles.

They occupy the spaces between the metacarpal bones, and are seven in number. Three of them, regarded as palmar, adduct the fingers towards the middle line of the hand; four, more dorsal in position, are abductors.

The **palmar muscles** are placed in the three inner interspaces. Each lies along the side of one finger, springing from the metacarpal bone, and being inserted by tendon partly into the first phalanx at the lateral aspect of the base and partly behind into the extensor tendons. The first belongs to the inner side of the index finger, the second and third to the outer sides of the ring and little fingers respectively.

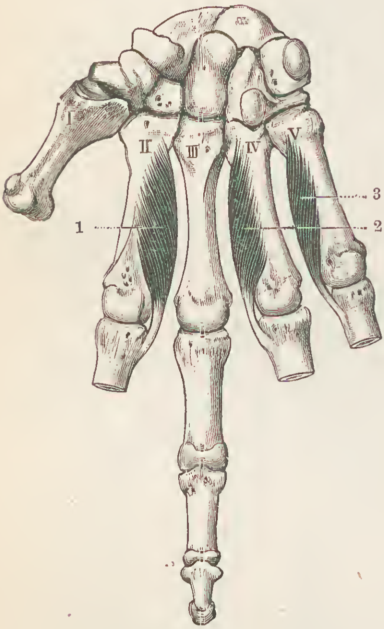


Fig. 246.—The Palmar Interosseous Muscles. (L. Testut.)

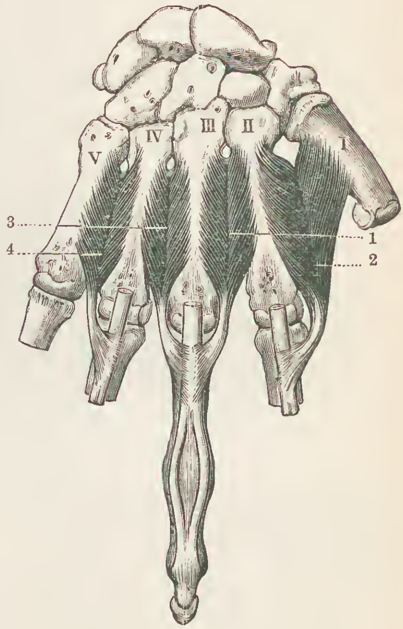


Fig. 247.—The Dorsal Interosseous Muscles. (L. Testut.)

The **dorsal muscles.** One occupies each interspace. Each takes origin by two heads, one from each of the two bones between which it is placed, and except in the case of the first or abductor indicis, the larger head is derived from the bone belonging to the finger on which the muscle acts. Each tendon is inserted into the first phalanx in a manner similar to the method of insertion of the palmar muscles. The first muscle belongs to the outer side of the index finger, the second and third to the outer and inner sides respectively of the middle finger, the last to the inner side of the ring finger.

Nerve supply of the muscles of the hand. These muscles are supplied by the median and ulnar nerves. The median supplies the abductor pollicis,

the opponens pollicis, the outer head of the flexor pollicis brevis, and the two outer lumbricales. The ulnar supplies all the others.

Actions of the Muscles of the Forearm and Hand.

The actions are in most cases indicated by the names of the muscles, and it is only requisite to give a special description in the case of one or two. Pronation is effected by the *pronator quadratus* and the *pronator radii teres*; the latter muscle also, when pronation has been completed or is prevented by the action of opposing muscles, assists in flexing the elbow. When the forearm is vigorously pronated, a rotatory movement of the humerus in the outward direction takes place, and this also is probably partly at least the result of the contraction of the pronator teres. Supination is brought about by the *biceps* and *supinator brevis.* The *supinator longus* assists in flexion of the elbow after that movement has been commenced by the other flexors, and is adequate of itself to maintain flexion; it has but little supinating action upon the radius.

The *ulnar and radial flexors and extensors of the carpus* oppose one another in flexion and extension of the wrist. When the flexors and extensors of the same side act together, lateral movement is produced at the joint. In addition, the long radial extensor may have in certain circumstances a slight flexing action upon the elbow. The *superficial and deep flexors of the fingers* act respectively upon the second and third phalanges, and are opposed by the *common extensor;* these muscles also act upon the wrist. The connections which pass between the tendons of the common extensor interfere, particularly in the case of the ring finger, with the independent extension of the separate digits. The index and little fingers, however, have each a special muscle, and can be individually extended with more freedom than either the ring or the middle finger. The *lumbricales* produce flexion at the metacarpo-phalangeal articulations and extension at the interphalangeal joints, as is exemplified in making the hair stroke in writing. The *interosseous muscles,* in addition to their own special action, assist the lumbricales; the dorsal set abduct the fingers from the middle line of the hand, while the palmar muscles adduct. The *palmaris longus* makes tense the fascia of the palm; the *palmaris brevis* dimples the skin at the inner side of the hand, and helps to deepen the hollow of the palmar cup.

Deep Fascia of the Forearm and Hand.

The fascia forms a moderately strong layer which closely invests all the superficial muscles, and, sending septa between them at their upper ends, affords origin to many of their fibres. It is attached to the internal and external epicondyles and the posterior border of the ulna, and receives fibres from the tendons of the biceps and triceps. At the bend of the elbow it is pierced by a vein of considerable size. At the lower and back part of the forearm it is considerably thickened to form the posterior

annular ligament; in front of the wrist the anterior annular ligament, much stronger than the posterior, is continuous superficially with the fascia.

The **anterior annular ligament**, a thick broad band, is fixed to the trapezium and scaphoid on the outer side, and to the pisiform bone and unciform process on the inner side. At its lower edge it is continuous with the palmar aponeurosis, and gives origin to some of the muscles of the thumb. The ulnar artery and nerve pass in front of the main body of the ligament, but are frequently covered by a few of the most superficial fibres. The median nerve and the tendons of the long flexors of the fingers and that of the thumb pass behind it. The tendon of the radial flexor of the carpus descends in a special canal at the outer attachment of the ligament.

The **posterior annular ligament** is not nearly so strong as the anterior ligament. It is fixed on the inner side to the pisiform bone, and on the outer side to the outer margin of the radius, but at both extremities it is further continued to blend with the fascia of the front of the limb. It is fixed on its deep surface to the ridges on the back of the radius and ulna and to the back of the capsule of the wrist-joint, and thus completed, a number of osteo-fibrous canals are formed, along which the extensor tendons pass.

Deep Fascia of the Hand.

Two layers of the deep fascia are found in the palm. One is more superficial, and covers the tendons of the long flexor muscles and the vessels and nerves, and spreads laterally as thin expansions over the thenar and hypothenar eminences; the other is more deeply placed, and invests the interosseous muscles and blends on either side, among the muscles of the thumb and little finger, with the lateral expansions of the superficial layer. Two vertical septa pass between the superficial and deep layers, and separate the regions occupied by the short muscles of the thumb and little finger respectively from the central space of the hand.

The **palmar aponeurosis** is the strong central portion of the superficial layer. It is triangular in outline, with its apex at the annular ligament. The fibres are chiefly longitudinal in direction, but towards the base a number of transversely running fibres, forming the superficial transverse ligament, are added. A little above the clefts of the fingers the longitudinally directed fibres of the aponeurosis are collected into four slips, one corresponding to each of the inner digits. Each slip, after detaching first a superficial bundle which passes downwards in front of the superficial transverse ligament to be attached to the skin at the base of a finger, is continued onwards on the deep surface of the superficial transverse ligament, and splits into two portions to give passage to the flexor tendons which descend upon the front of the digit; the portions into which each slip splits are attached to the metacarpo-phalangeal ligaments, and blend with

the deep transverse ligament. The *superficial transverse ligament* is formed of a few transversely running fibres, and is placed in front of the digital slips, from each of which it receives a small accession.

The lateral expansions of the palmar aponeurosis cover and invest the muscles of the thumb and little finger, and are continuous at the borders of the hand with the fascia of the dorsum.

In the central part of the palm lie the tendons of the flexor muscles of the digits, the lumbricales muscles and a number of the palmar digital vessels and nerves; these structures lie behind the strong central part of the palmar aponeurosis and in front of the interosseous fascia. The flexor tendons which descend upon the anterior surfaces of the fingers pass through the digital slips of the palmar aponeurosis; the vessels and nerves and the lumbricales' tendons, which descend upon the sides of the fingers, pass between the slips and behind the superficial and in front of the deep transverse ligament; the tendons of the interosseous muscles descend behind the deep transverse ligament.

The **interosseous fascia** forms a delicate layer, which covers in front the interosseous muscles, and laterally blends with the fascia which invests the short muscles of the thumb and little finger. At its lower extremity it is continuous with the *deep transverse ligament*, a strong band which crosses in front of the lower extremities of the four inner metacarpal bones, and is blended with the metacarpo-phalangeal ligaments and the digital slips of the palmar aponeurosis.

The septa which pass between the palmar aponeurosis and the interosseous fascia are of a delicate nature. The inner of the two separates the muscles of the little finger from the central part of the palm, and is pierced by the superficial palmar arch of artery and a digital branch of the ulnar nerve; the outer separates the muscles of the thenar eminence from the central part of the palm—it is pierced by the palmar digital nerves for the outer side of the index finger and for the thumb.

The **deep fascia of the dorsum** is found in two comparatively thin layers. The more superficial is continuous with the lower edge of the posterior annular ligament and the lateral expansions of the palmar fascia, and covers and is closely associated with the extensor tendons. The deeper invests the surface of the interosseous muscles, and is attached to the metacarpal bones.

THE LOWER LIMB.

MUSCLES OF THE HIP.

The muscles of this region are the gluteus maximus, gluteus medius, gluteus minimus, pyriformis, gemellus superior, obturator internus, gemellus inferior, quadratus femoris, and obturator externus. With the gluteus medius and gluteus minimus the tensor vaginae femoris is closely associated. With the exception of the last they are inserted into the

great trochanter or in its immediate neighbourhood. The gluteus maximus and tensor vaginae femoris are entirely superficial; the gluteus medius is partially so; the others are deeply placed.

The **gluteus maximus**, a large four-sided muscle, extending downwards and outwards, arises from the posterior fifth of the iliac crest and the small adjoining area of the dorsum ilii, from the lower part of the posterior layer of the lumbar aponeurosis, from the margin of the posterior surface of the lower half of the sacrum and upper half of the coccyx, and from the posterior surface of the great sacro-sciatic ligament; fibres also spring

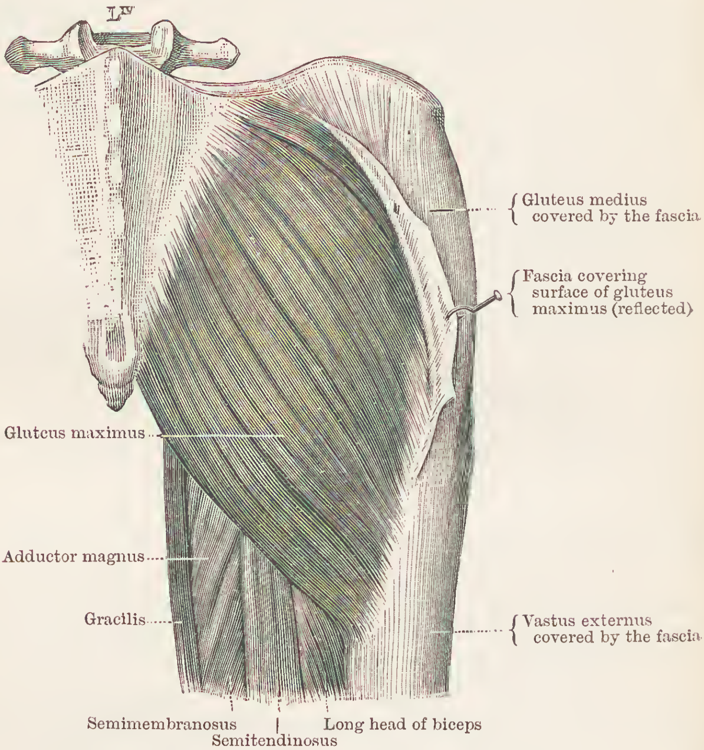


FIG. 248.—MUSCLES OF THE HIP, superficial layer. (L. Testut.)

from the fascia on the deep surface of the muscle. The deeper fibres of the lower part of the muscle are inserted into the rough gluteal ridge of the femur, extending from the outer lip of the linea aspera towards the great trochanter. The remainder, forming the larger part, passes into the fascia lata of the upper and outer part of the thigh.

At the insertion into the fascia the tendinous fibres cover the great trochanter, a large bursa being interposed; the lower margin of the muscle in sweeping outwards crosses the upper part of the ischial tuberosity. On its deep aspect lie the upper part of the adductor magnus, the origins of the hamstrings, the quadratus femoris, and gemelli, and

portions of the obturator internus, pyriformis, and gluteus medius muscles, and the vessels and nerves which escape by the great sacro-sciatic foramen. It is supplied by the inferior gluteal nerve from the sacral plexus.

The **gluteus medius**, fan-shaped, arises from the large area of the dorsum ilii, limited above by the middle three-fifths of the crest and the superior curved line, and below by the middle curved line; fibres also spring from the strong fascia which overlies the surface of the muscle, where it is uncovered by the gluteus maximus. It is inserted by a short tendon into the oblique line running downwards and forwards upon the outer

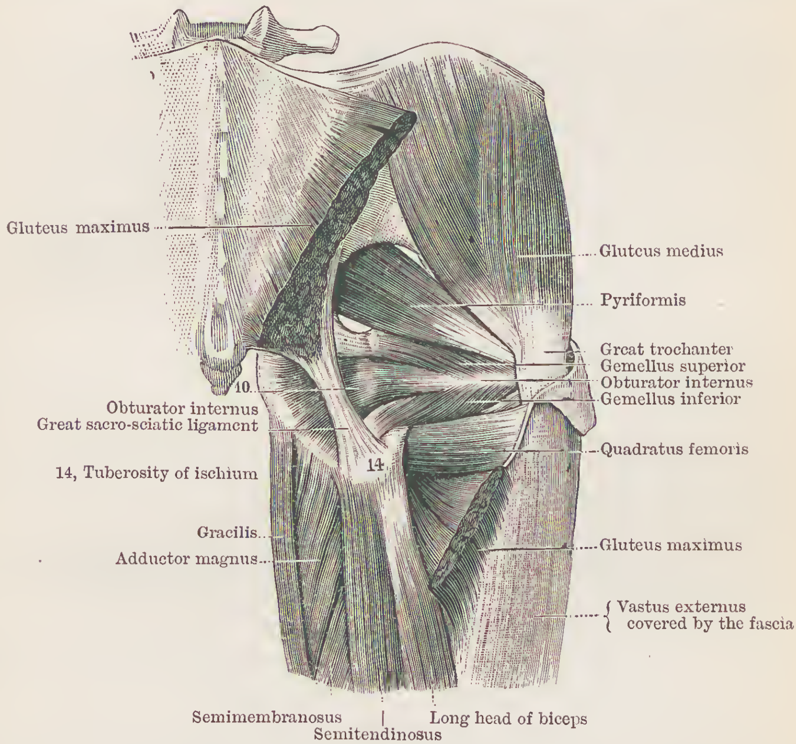


FIG. 249.—MUSCLES OF HIP, deep layer. (L. Testut.)

surface of the great trochanter, a bursa being interposed close to the insertion between the tendon and the bone. The anterior fibres are directed downwards and slightly backwards, the posterior downwards and forwards. The muscle is partially concealed by the gluteus maximus and nearly completely covers the gluteus minimus. It is supplied by the superior gluteal nerve from the sacral plexus.

The **gluteus minimus**, very similar in shape to the gluteus medius, arises from the area of the dorsum ilii between the middle and inferior curved lines. It is inserted by a tendon into the anterior border of the great trochanter, a small bursa being interposed close to the insertion.

The deep surface of the tendon is united by a strong band of aponeurotic fibres, which is closely associated with a band from the portion of the fascia lata connected with the tensor vaginae femoris, to the capsule of the hip-joint and the acetabular margin, in close proximity to the reflected tendon of the rectus femoris. The anterior borders of the two smaller gluteal muscles are closely associated with one another and with the posterior surface of the tensor vaginae femoris. The pyriformis behind overlaps the minimus and is often partially incorporated with the medius. The gluteus minimus is supplied by the superior gluteal nerve.

The **tensor vaginae femoris** (*tensor fasciae latae*) arises from a narrow area of the dorsum ilii immediately behind, and extending for a short distance above and below, the anterior superior spine. It is directed downwards and slightly backwards as a somewhat narrow band on the outer aspect of the upper third of the thigh and ends in the fascia lata. On the deep surface of the muscle a strong slip of fascia extends upwards to the capsule of the hip-joint, which it joins in connection with the fibres from the gluteus minimus tendon. The portion of fascia lata in direct continuity with the muscular insertion passes downwards as the ilio-tibial band to the external lateral patellar ligament and the outer tuberosity of the tibia. Like the two smaller gluteal muscles with which it is so closely associated at its origin, it is supplied by the superior gluteal nerve.

The **pyriformis** arises within the pelvis from the anterior surface of the second, third and fourth pieces of the sacrum. It passes as a fleshy mass outwards through the great sacro-sciatic foramen, and narrows near its insertion to a rounded tendon which is attached to the upper border of the great trochanter, and is usually firmly bound to the subjacent tendon of the obturator internus. The muscle is supplied by special branches from the sacral plexus. The great sciatic nerve emerges from the pelvis at the lower border of the pyriformis and descends behind the gemelli, the obturator internus, and the quadratus femoris.

The **obturator internus** arises within the pelvis. Its deeper fibres spring from the anterior three-fourths of the obturator membrane, the more superficial from the edges of the foramen arising in a semicircular line, which begins below at the lower and passes round the anterior and upper margins, and extends backwards into the angle between the ilio-pectineal line and the sacro-sciatic notch. The line of origin from the bone is interrupted opposite the groove on the upper margin of the foramen; fibres also spring from the fascia on the inner surface of the muscle. The fibres converge rapidly and form a narrow band, tendinous and partially divided into four in front and muscular behind, which turns over the smooth fibro-cartilaginous surface between the ischial spine and tuberosity. It is inserted, along with the gemelli and in close contact with the pyriformis, by a rounded tendon into the anterior region of the inner surface of the great trochanter. A

large bursa lies between the tendon and the fibro-cartilaginous surface, and is sometimes continued on to the back of the capsule of the hip-joint. The muscle is supplied by a special branch from the sacral plexus.

The **gemelli**, narrow fleshy bundles, are placed one above and the other below the extra-pelvic portion of the obturator internus and overlap it, the superior and smaller chiefly on the posterior aspect, the inferior chiefly in front. The superior arises from the base of the ischial spine, the inferior from the tuberosity and the outer lip of the trochlear surface. They are inserted with the tendon of the obturator internus. The three muscles

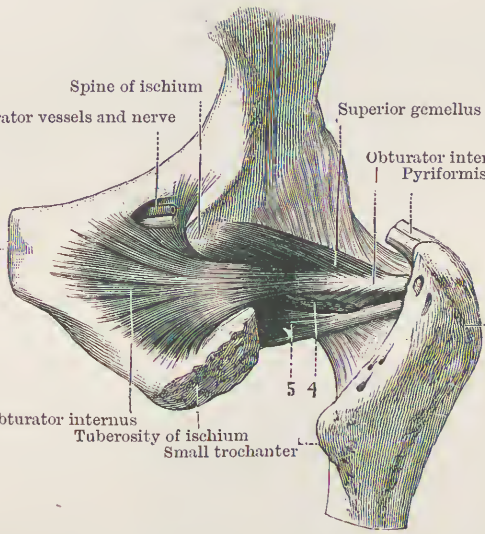


FIG. 250.—GEMELLI AND OBTURATOR MUSCLES, from behind. (L. Testut.)

cross the posterior surface of the capsule of the joint, and are attached to it by fascia. The superior is supplied by a special branch from the sacral plexus, the inferior by a nerve from the same source, common to it and the quadratus femoris.

The **quadratus femoris**, small, four-sided, and fleshy, springs from the outer margin of the ischial tuberosity. It is inserted into the posterior margin and outer surface of the great trochanter, extending as far down as the level of the upper border of the small trochanter. The muscle conceals the tendon of the obturator externus. Its lower border is in contact with the upper edge of the adductor magnus. It is supplied from the sacral plexus.

The **obturator externus** takes origin from the outer surface of the wall of the pelvis. It springs from the bony margin of the anterior half of the obturator foramen, and from the anterior half of the obturator membrane. Narrowing rapidly to a flattened band, it passes outwards beneath the acetabulum, then outwards and upwards across the posterior surface of the

capsule of the joint, a bursa being interposed. It is inserted by tendon into the digital fossa of the trochanter. It is supplied by the obturator nerve from the lumbar plexus.

Variations of the muscles of the hip. Some of the smaller muscles are sometimes entirely absent, most frequently the superior gemellus; but absence of the inferior gemellus, of the quadratus femoris, and of the pyriformis has occasionally been observed. Contiguous muscles are sometimes united with one another thus—the quadratus femoris with the adductor magnus, and the pyriformis with the gluteus medius, minimus, or gemellus superior. The gluteus maximus is sometimes divided into two layers, and its lowest sacro-coccygeal fibres are sometimes distinct from the others, representing the agitator caudae of the lower animals. The gluteus medius is sometimes double at its insertion, and the minimus is occasionally almost completely divided into two parts. The pyriformis is very frequently divided into two by one of the roots of the great sciatic nerve. An accessory gluteal muscle has been found between the maximus and medius.

POSTERIOR FEMORAL REGION.

The hamstring muscles,—biceps, semitendinosus and semimembranosus, —passing from the tuberosity of the ischium to the outer and inner sides of the knee, occupy the back of the thigh. They spring from two triangular impressions on the upper and posterior region of the tuberosity, the biceps and semitendinosus by a common tendon from the internal and lower of the two, the semimembranosus from the upper and outer. The biceps has an additional head from the linea aspera.

They lie behind the quadratus femoris and adductor magnus, and are themselves covered posteriorly in the upper part of the thigh by the gluteus maximus. As they separate above the knee, the biceps to the outside, the other two inwards, they form the upper walls of the diamond-shaped popliteal space completed below by the heads of the gastrocnemius. They are supplied by the great sciatic nerve which descends in front of them.

The **biceps** (*biceps femoris*). The tendon of the long head, arising from the ischial tuberosity in common with the semitendinosus, separates from that muscle in the upper fifth of the thigh. Almost immediately afterwards it enlarges into a rounded muscular belly, which above the knee is joined by the short head, a broad fasciculus of muscular fibres springing from the outer margin of the linea aspera, the upper part of the external supracondylar line and the external intermuscular septum. The muscle terminates in a short divided tendon which is inserted into the outer surface of the head of the fibula on either side of the long part of the external lateral ligament of the knee-joint, a bursa intervening. Fibres from the tendon pass forwards to the outer side of the head of the tibia and to the fascia of the leg.

The **semitendinosus** springs by muscular fibres from the inner surface of the tendon common to it and the long head of the biceps. The muscular belly consists of longitudinal fibres interrupted about the middle

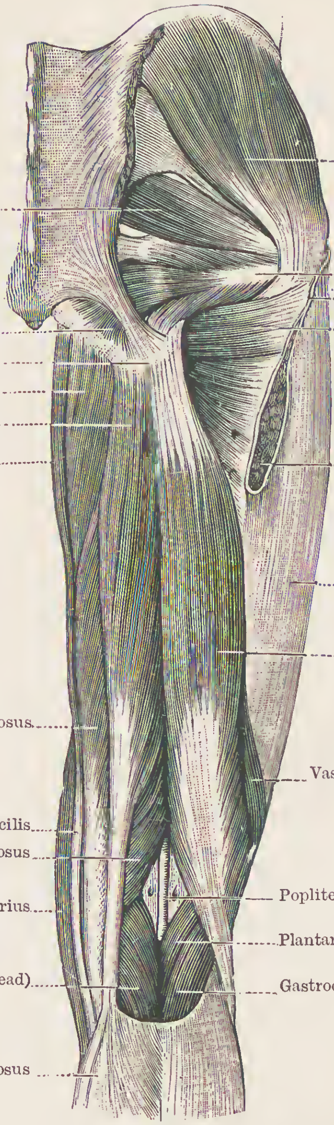


Fig. 251.—Muscles of the Posterior Region of the Thigh. (L. Testut.)

by an oblique tendinous intersection, and narrows in the lower third of the thigh to a slender rounded tendon which, becoming expanded, is inserted behind that of the sartorius, and below, but in the same plane with that of the gracilis, into the inner surface of the shaft of the tibia

at its upper end. Some fibres are detached from the tendon to the fascia of the leg. A bursa lies between the tendons and the internal lateral ligament of the knee-joint.

The **semimembranosus**, springing from the upper and outer facet upon the ischial tuberosity by a broad tendon, membranous in the greater part of its breadth and several inches in length, terminates below in a tendon which divides into three portions—one detached to the fascia covering the popliteus muscle, another to the posterior surface of the capsule of the knee, the third passing forwards under cover of the internal lateral ligament of the joint to the extremity of the groove on the inner surface of the head of the tibia. The muscular belly is formed of short oblique fibres running between the tendon of origin which is continued downwards for some distance on its outer side and the tendon of insertion continued upwards on the inner side, and thus possesses greater force and smaller extent of contraction than the other hamstring muscles. Close to its origin it passes in front of the outer part of the common tendon of the other hamstrings, and thereafter is continued down the thigh along the anterior edge of the semitendinosus. A bursa separates the tendon of insertion from the inner head of the gastrocnemius. The groove in which a portion of the tendon lies is lined by firm fibrous tissue and lubricated by a synovial membrane.

Variations of the posterior femoral muscles. The short head of the biceps may be absent, and sometimes, though very rarely, the semimembranosus is absent. On the other hand, an additional head of the biceps is occasionally found springing from the internal supracondylar line, the linea aspera, or the ischium. An additional head of the semimembranosus may be present, springing from the linea aspera.

INNER FEMORAL REGION.

The muscles of this group are the gracilis, pectineus, adductor longus, adductor brevis, and adductor magnus. At their origins they occupy the anterior surface of the pubis and ischium, above, to the inner side of, and below the obturator externus. The gracilis passes downwards to the inner side of the knee. The others pass outwards, downwards and slightly backwards towards the linea aspera and the lines continued from it. At the insertion the pectineus, adductor brevis, and adductor longus lie in order from above downwards in front of the adductor magnus, but the adductor brevis is overlapped by the lower edge of the pectineus. The upper part of the inner edge of the adductor longus forms on the front of the upper third of thigh, the inner boundary of a triangular area, *Scarpa's triangle*, the outer margin of which is formed by the upper part of the sartorius and the floor by the pectineus and portions of the iliacus, psoas, adductor brevis, and adductor longus. From base to apex of this space the femoral artery passes downwards in the thigh. After traversing

the space the artery crosses the insertion of the adductor longus, and still further down passes backwards through the adductor magnus to the popliteal space. From the anterior surface of the insertions of the adductor longus and adductor magnus in the middle third of the thigh, membranous fibres crossing the femoral vessels pass outwards to the vastus internus and form the anterior wall of a three-sided passage called *Hunter's canal.* The deep femoral branch of the main arterial stem courses behind the adductor longus and gives off a number of perforating branches which pass backwards through the adductor magnus to the posterior region of the thigh.

The muscles, with the exception of the pectineus, are supplied by the obturator nerve. The pectineus receives its supply from the anterior crural but has an occasional twig from the obturator. The adductor magnus receives an additional twig from the great sciatic.

The **gracilis** springs by a short, thin tendon from the rough line close to the symphysis on the lower part of the body of the pubis, and from the anterior margin of the pubic portion of the ischio-pubic ramus. The body of the muscle, flattened and slender, passes down superficially on the inner aspect of the thigh, and narrows in the lower third to a tendon which, somewhat expanded at its termination, is inserted behind the sartorius and above the semitendinosus into the inner surface of the shaft of the tibia at the upper end.

The **pectineus** arises from the ilio-pectineal line and the smooth surface in front of it in the region between the spine of the pubis and the ilio-pectineal eminence. It is inserted into the upper part of the line leading from the linea aspera to the back of the small trochanter. Superficial at its origin it rapidly passes backwards in the floor of Scarpa's triangle. The ilio-psoas muscle is in contact with it externally.

The **adductor longus,** triangular in outline, springs by a short, narrow tendon from the body of the pubis at the anterior and inner angle. It is inserted by aponeurotic fibres closely associated with the insertion of the adductor magnus into the inner edge of the linea aspera. In its greater part it is superficial, but near its insertion it is crossed by the femoral vessels and the sartorius. The pectineus lies at its outer edge, the gracilis internally, the adductor brevis is posterior to it at its origin, and the adductor magnus is behind it lower down.

The **adductor brevis,** deeply placed, springs from the body of the pubis below the adductor longus and between the gracilis and obturator externus. It is inserted into the line leading from the linea aspera to the back of the small trochanter, lying behind the lower portion of the pectineus above and reaching to the adductor longus below. The muscle is frequently split into two portions at its insertion by the first perforating branch of the deep femoral artery.

The **adductor magnus** springs from the surface of the ischio-pubic ramus, and in addition spreads in its origin backwards on the tuberosity as far as the

margin of the quadratus femoris and forwards upon the body of the pubis into the angle between the origins of the adductor brevis and obturator externus. The anterior part of the origin is overlapped by the gracilis, the

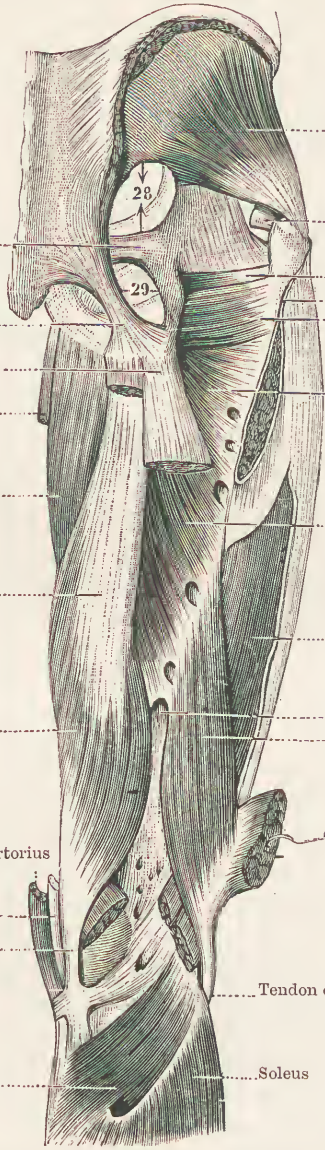


FIG. 252.—POSTERIOR REGION OF THIGH, deep dissection (compare Fig. 251). (L. Testut.)

posterior part is subcutaneous. It is inserted into the back of the femur, behind the other muscles of the group, along a line which extends from the upper extremity of the gluteal ridge to the adductor tubercle. The fibres

most anterior at their origin pass almost directly outwards to the inner margin of the gluteal ridge; those succeeding are oblique in direction and are inserted by short tendinous fibres into the inner margin of the linea aspera and the upper third of the supracondylar line; the most posterior fibres descend almost vertically behind the others to the adductor tubercle, where they are inserted by a rounded cord-like tendon. Through the break in the insertion opposite the greater part of the supracondylar line the femoral vessels pass. Three or four smaller openings at intervals along the line of insertion transmit the perforating arteries. The posterior part of the muscle is superficial above, below it is covered by the gracilis and semimembranosus.

Variations of the internal muscles of the thigh. Contiguous muscles are frequently found more or less united with one another—thus, the adductor longus with the pectineus, and the adductor magnus with the longus, brevis, or quadratus femoris. The adductor brevis and pectineus are occasionally found in two portions, and in the case of the adductor magnus the upper and lower fibres are sometimes quite separate from the rest of the muscle. Variations in extent of attachment are not very frequent in this group, but the pectineus is sometimes found connected with the capsule of the hip-joint.

ANTERIOR FEMORAL REGION.

The muscles of this group are the sartorius, quadriceps extensor femoris, and the ilio-psoas. The sartorius and a portion of the quadriceps cross both hip- and knee-joints; of the others, the ilio-psoas acts upon the hip, the remainder of the quadriceps upon the knee. They are, with the exception of the psoas, supplied by the anterior crural nerve. The psoas is supplied by special branches from the lumbar plexus.

The **sartorius**, long, narrow and superficial, and formed of longitudinal bundles which run the whole length of the muscle, arises from the anterior margin of the ilium, the origin extending for a short distance downwards from the anterior superior spine. It is inserted by a thin expanded tendon which detaches fibres to the fascia of the leg and the capsule of the knee-joint into the inner surface of the shaft of the tibia at its upper end in front of the tendons of the gracilis and semitendinosus. In the upper portion of the thigh the muscle is directed downwards and inwards; afterwards nearly directly downwards, near its insertion, the tendon bends forwards. It crosses the rectus femoris, ilio-psoas, pectineus, adductor longus, the femoral vessels, and vastus internus, and forms in the upper part of the thigh the outer boundary of Scarpa's triangle.

The **quadriceps extensor cruris** is formed of four parts—the rectus femoris, vastus externus, vastus internus, and crureus, which have a common insertion into the patella. The rectus femoris, the most superficial, and distinct almost to its insertion, springs from the hip-bone and

occupies the middle of the front of the thigh. The others, very closely associated with one another in their whole extent, take origin from the

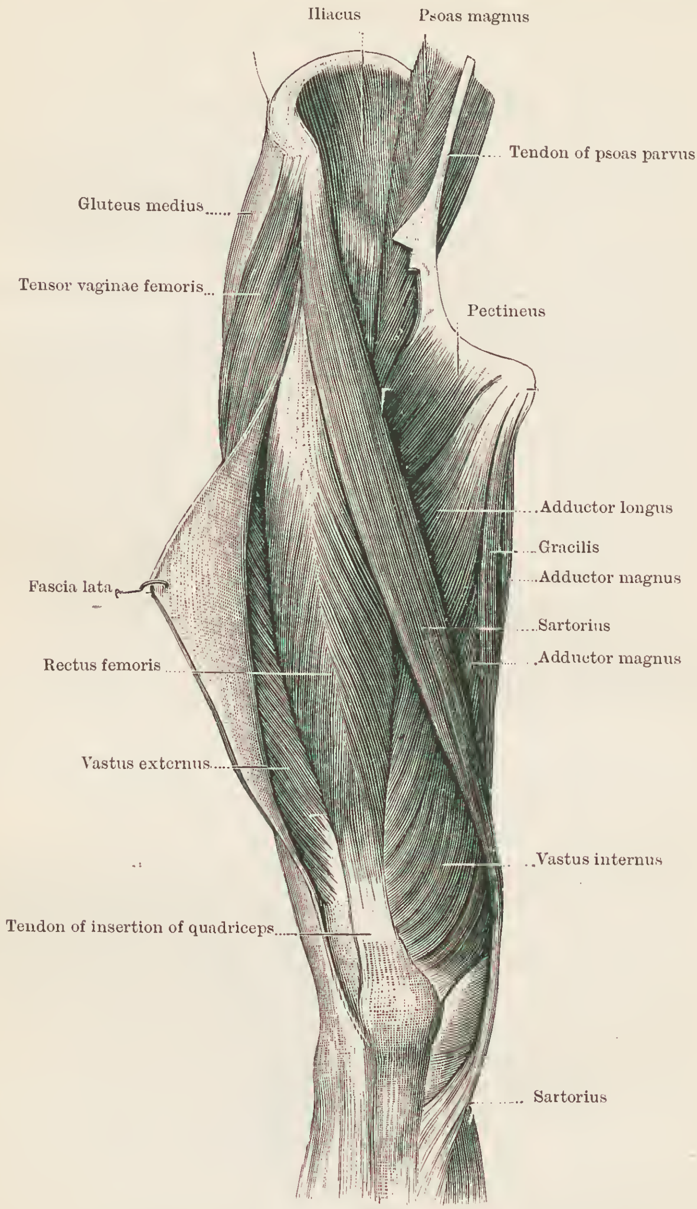


Fig. 253.—Anterior Region of Thigh, superficial. (L. Testut.)

femur, the crureus between the other two, and closely cover the surface of the bone. The common insertion is centred round the strong tendon of the rectus femoris, which passes to the middle of the upper border

and the anterior surface of the patella, and is joined on its deep surface by the crureus tendon and on its margins above the bone by fleshy fibres from the vasti, and a little lower by their tendons which reach the lateral portions of the upper border of the patella and the lateral patellar regions of the knee capsule. A large bursa communicating with the joint lies underneath the common insertion. From the lower margin of the patella the *ligamentum patellae* passes to the anterior tubercle of the tibia.

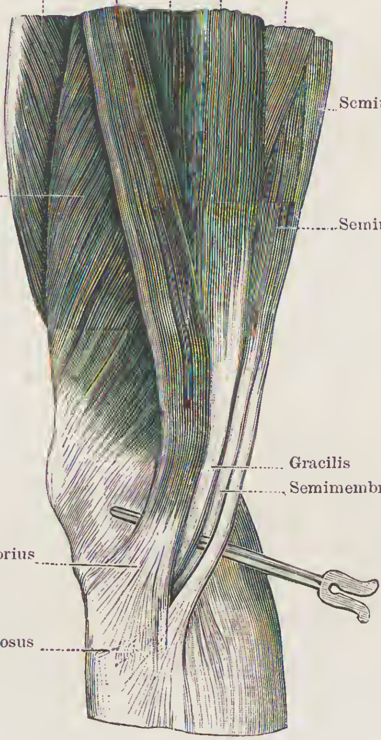


FIG. 254.—INNER SIDE OF THE KNEE. (L. Testut.)

The **rectus femoris** arises by two very short, strong, tendinous heads—one, the reflected tendon from the rough mark on the upper and outer border of the acetabulum, the other, the straight tendon from the anterior inferior iliac spine. These unite with one another at an angle of about 45 degrees, and form a rounded tendon. The muscular belly occupies the middle three-fifths of the thigh, but consists of short oblique fibres stretching from the tendon of origin which passes downwards for some distance in the muscular substance to the tendon of insertion, which is prolonged upwards on the deep surface. The origin is deeply placed, being covered by the iliacus and gluteus minimus and crossed by the sartorius; the rest of the muscle is superficial.

The **vastus externus**, a thick muscular sheet occupying the outer region of the thigh, and presenting an anterior border free from the crureus in its whole extent, springs partly by an aponeurosis which extends for some distance on the surface of the muscle and partly by fleshy fibres from the upper part of the anterior intertrochanteric line, the line limiting the great trochanter in front and to the outside, the outer margin of the gluteal ridge, and the upper portion of the linea aspera; fibres also spring from the external intermuscular septum. The fibres pass downwards and inwards to the tendon, which forms on the deep surface of the muscle in its lower part and joins the outer part of the common insertion. The muscle is superficial in the greater part of its extent, being only slightly overlapped by the rectus and tensor vaginae femoris. It lies upon the crureus.

The **vastus internus** arises partly by aponeurotic and partly by fleshy fibres from the lower extremity of the anterior intertrochanteric line, from the line leading thence to the linea aspera, and from the inner lip of the linea aspera. The origin is closely connected behind with the insertions of the adductor longus and adductor magnus. The fibres pass outwards and downwards, and the muscle lies close upon the bone. Its most anterior fibres pass into the superficial aponeurosis of the crureus, and the muscle therefore contrasts with the vastus externus in having no free border in front. If the muscular mass be divided from below upwards, however, it will be found that there is no continuity between the crureus and vastus internus at their origins, and that there is a continuous tract along the whole inner surface of the femur from which no muscular fibres spring. The remainder of the fibres pass to a tendon which forms on the deep surface of the muscle, and joins the inner part of the common insertion. The muscular fibres of the vastus internus are continued further downwards towards the patella than are those of the vastus externus. The muscle is overlapped by the rectus and crossed by the sartorius, but in the space between these two it is superficial. The femoral vessels are for some distance in contact with its surface.

The **crureus** springs from the outer portion of the shaft of the femur and extends in its origin from the anterior intertrochanteric line to within a few inches of the lower end of the bone; some of the lower fibres spring from the external supracondylar line and external intermuscular septum. It is largely overlapped by the vastus externus, with the origin of which it is at its posterior margin continuous. Its aponeurosis of insertion joins the deep part of the common tendon, and is continued upwards over the anterior surface of the muscle, presenting to the posterior surface of the rectus, which is similarly covered, an aponeurotic expansion which allows gliding.

A few of the lower fibres of the muscle receive the name of *subcrureus*. They are attached to the wall of the synovial bursa which lies behind the common tendon of insertion.

The **ilio-psoas**, arising and chiefly contained within the abdomen, is formed of two parts which, distinct above, are united and inserted together below.

The **iliacus** occupies the iliac fossa and springs from the broad marginal area, extending from the region of the anterior inferior spine

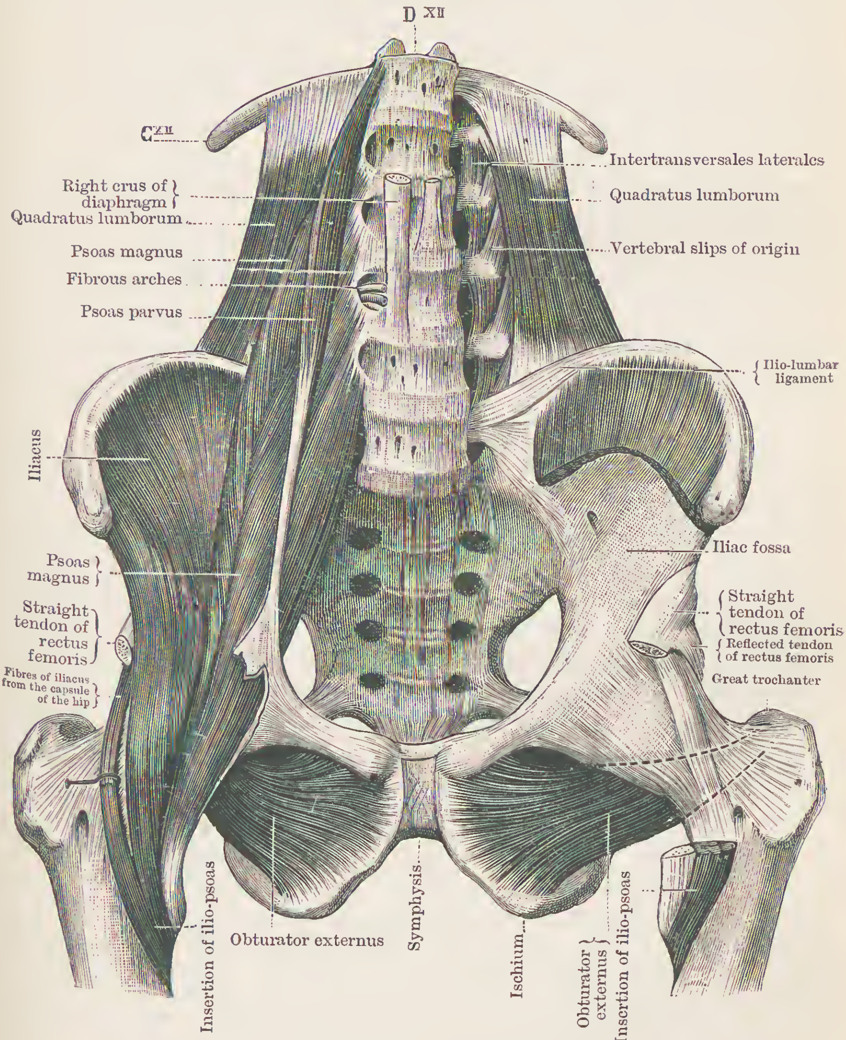


FIG. 255.—THE ILIO-PSOAS MUSCLE. (L. Testut.)

upwards and backwards to the sacro-iliac ligaments and edge of the sacrum. It crosses the capsule of the hip, from which sometimes a few of the lower fibres take origin, and is inserted partly into the outer edge of the psoas tendon and partly into the triangular area in front of and below the small trochanter.

The **psoas magnus** occupies the angle between the anterior surfaces of the tranverse processes and the lateral regions of the bodies of the lower movable vertebrae, its origin extending from the last dorsal to the fifth lumbar. The fibres spring partly from the transverse processes, on which they reach outwards nearly to the tips, partly from the intervertebral discs and the contiguous bony vertebral margins, and partly from a series of tendinous arches which, crossing the lumbar vessels, stretch from the upper to the lower edges of the bodies of the vertebrae. Narrowing as it passes downwards it first partly overlaps and then becomes united with the inner edge of the iliacus, crosses the capsule of the hip, and is inserted by tendon into the small trochanter.

In the abdomen both muscles are covered by the iliac fascia. The psoas is crossed by the external iliac artery which, while still on its surface, passes behind Poupart's ligament. At its origin the lumbar plexus of nerves lies deeply embedded in it and the branches leave it at various points. In the thigh the conjoined muscles form part of the floor of Scarpa's triangle. Between the deep surface of the psoas and the capsule of the hip lies a large bursa which often communicates with the cavity of the joint.

The **psoas parvus**, inconstant and variable, lies, when present, upon the surface of the larger psoas muscle. It usually springs from the intervertebral disc which unites the last dorsal to the first lumbar vertebra and from the contiguous edges of the bones. Rapidly narrowing, it ends in a long tendon which, passing downwards and becoming partly blended with the iliac fascia, is inserted into the ilio-pectineal eminence. The muscle though well developed and constant in many animals is absent in the human subject, on one or both sides, in about fifty per cent. of cases.

Variations of the anterior femoral muscles. These are not frequent. Absence of the sartorius has been noted. Additional attachments of the sartorius, psoas and iliacus have been described. The two last mentioned muscles are sometimes completely separated down to their attachments.

Actions of the Muscles of the Hip and Thigh.

The *gluteus maximus* is the chief extensor of the hip-joint, and may act from the thigh or from the trunk. Acting from the trunk the upper fibres tend to abduct the thigh while the lower fibres adduct and rotate outwards. The whole muscle comes into play in walking, running, leaping, and in rising from the sitting to the erect posture. Through its connection with the fascia lata the muscle acts along with the tensor vaginae femoris upon the knee-joint. The *gluteus medius* and *minimus* are abductors of the thigh, or, acting from the thigh, tilt the pelvis over the femur, as happens in walking in the case of the supporting limb. The anterior fibres of both muscles tend to rotate the limb inwards, more particularly in the flexed position of the joint. The posterior fibres of the gluteus medius act as

extensors and, to a slight extent, as rotators outwards. The *tensor vaginae femoris* acts upon the tibia through the ilio-tibial band, and on the femur through the external intermuscular septum; it is a rotator inwards, and an abductor of the thigh, and is an extensor of the knee-joint and a rotator outwards of the tibia. In the completion of the extension of the knee it both rotates the femur directly and holds the tibia firm, and in the flexed position of the knee it acts with the biceps in rotating the leg outwards opposing the sartorius, gracilis, semitendinosus, and semimembranosus, which all rotate the leg inwards. The *pyriformis* is an abductor and to a slight extent an extensor and rotator outwards of the thigh; the *obturator internus* and *gemelli* are rotators outwards; like the other muscles at the back of the joint they act upon the trunk in walking, assisting to tilt the pelvis over the supporting limb. The *quadratus femoris* and *obturator externus* are outward rotators and have in addition a slight adducting action upon the limb.

The *adductor muscles* may act either from the trunk or from the femur. They oppose the gluteus medius and minimus and thus come into play in walking, in balancing the trunk upon the limb. The *pectineus, adductor longus* and *adductor brevis* assist in flexing the thigh. The *gracilis* flexes the knee and rotates the tibia inwards. The posterior fibres of the *adductor magnus* would assist in extension of the hip. The *hamstring muscles* extend the hip and flex the knee. With bent knee they rotate the leg—the biceps outwards, the other two inwards. The *rectus femoris* flexes the hip and extends the knee; the *vasti* and *crureus muscles* extend the knee. The anterior origin of the rectus is the only one tightened when the thigh is extended, and the posterior the only one tightened when the thigh is flexed. The *sartorius* flexes both hip and knee, everts the thigh and rotates the leg inwards. The *ilio-psoas* flexes the thigh, and may act either from the trunk or from the femur; acting from below the psoas can produce lateral flexion of the lumbar portion of the column.

In walking while the swinging limb is passing forwards, chiefly from the action of gravity after the knee has been bent, the weight of the body is supported by the trunk being drawn over the other limb. The gluteus maximus acts as the chief extensor; the gluteus medius, gluteus minimus and the external rotators bring about the lateral tilting of the pelvis, their action being opposed and modified by the adductor muscles which assist in maintaining the balance of the body. When the stride taken is longer than the natural step the action of the ilio-psoas is required to carry the femur forwards.

DEEP FASCIA OF THE THIGH.

The deep fascia of the thigh, or *fascia lata*, is attached above to Poupart's ligament, the body and inferior ramus of the os pubis, the ischium, the great sacro-sciatic ligament, the lower part of the lumbar aponeurosis and the crest of the ilium. Below, it sweeps on the inner side and behind

into the fascia of the leg; at the outer side it is fixed to the head of the fibula and the external tuberosity of the tibia; and in front, becoming blended with the insertions of the quadriceps muscle, it is attached to the patella, assisting to form the lateral patellar ligaments and the capsule of the knee. A thin layer, sweeping over the patella, incloses the large prepatellar bursa which, when inflamed and swollen, is the seat of the affection known as "housemaid's knee." The fascia, which is generally strong, is specially strengthened on the outer aspect of the thigh, where it receives the attachment of the greater part of the gluteus maximus muscle and of the tensor vaginae femoris. From the insertion of the latter muscle at the junction of the upper and middle thirds of the thigh, a strong portion of the fascia, described as the *ilio-tibial band*, passes downwards and is attached partly to the external tuberosity of the tibia and partly to the patella, assisting to form the external lateral patellar ligament. The *external intermuscular septum* of the thigh is closely connected with the deep surface of the ilio-tibial band; it passes to the linea aspera between the biceps and vastus externus muscles, affording origin to both, and is specially strong at its lower end where it reaches the back of the external condyle of the femur. On the deep aspect of the tensor vaginae femoris a strong process of the fascia passes upwards and is attached, in association with a band of tendinous fibres from the tendon of the gluteus minimus, into the capsule of the hip-joint and the acetabular margin at the place of origin of the reflected tendon of the rectus femoris. On the posterior aspect of the limb a strong layer passes on the deep surface of the gluteus maximus, assisting to inclose the muscle and affording origin to many of its fibres. A delicate *posterior intermuscular septum* is sometimes described as passing to the linea aspera behind the adductor muscles. The fascia is weakest over the inner region of the thigh.

The *internal intermuscular septum*, much weaker than the outer, passes to the linea aspera between the vastus internus and the adductor muscles, and becomes blended with the sheath of the femoral vessels. Closely associated with the femoral sheath and the internal intermuscular septum is the short passage in the middle third of the thigh, known as *Hunter's canal.* The canal is formed in the angle between the attachment of the vastus internus in front, and those of the adductor magnus and adductor longus behind, by strong tendinous fibres which pass between the muscles and limit a passage, three-sided, in cross section, which transmits the femoral artery and vein and the long saphenous nerve. The canal extends upwards from the margin of the lowest perforation in the insertion of the adductor magnus for two or three inches, but its upper extremity is not well defined, as the tendinous fibres which complete its walls gradually become weaker and are continuous with the femoral sheath.

The *saphenous opening* is a large perforation of the fascia on the anterior aspect of the thigh for the transmission of the saphenous vein and a number of smaller vessels. It is placed below the inner part of

Poupart's ligament, and is formed by a splitting of the fascia into two portions, an inner and an outer. The inner or pubic portion passes upwards and is attached to the first half-inch of the ilio-pectineal line, along the line of attachment of Gimbernat's ligament; traced outwards it is deflected behind the femoral vessels, becoming continuous with the posterior wall of their sheath, and covers the pectineus muscle. The outer or iliac portion of the fascia passes upwards to Poupart's ligament; its inner margin is sickle-shaped and forms the outer boundary of the saphenous opening. The sickle-shaped or falciform margin is divided into three regions—an *upper* and a *lower falciform process*, both well marked,

FIG. 256.—THE SAPHENOUS OPENING.

and an intermediate portion, not so distinctly outlined, where there is a close connection between the fascia lata and the *cribriform fascia*, the layer of superficial fascia which immediately overlies the opening. The femoral sheath is formed, in its upper part, of a prolongation of the fascia transversalis and fascia iliaca of the abdominal walls. The artery and vein are contained in different compartments, separated from one another by a delicate septum, the vein being the more internal. Immediately internal to the vein, however, a third compartment, short, and ending in a blind pointed extremity, about half an inch below Poupart's ligament, contains a small lymphatic gland and some fatty tissue. A femoral hernia descends in this compartment and, stretching the walls of the sheath, passes to the surface through the saphenous opening.

EXTERNAL REGION OF THE LEG.

The muscles of this region are the peroneus longus and the peroneus brevis. Their origins occupy the whole outer surface of the fibula with the exception of the lower fourth, and, for a little distance about the middle of the bone, overlap, the upper part of the brevis stretching upwards in front of the lower part of the longus. The origin of the longus is pierced by the external popliteal nerve. Intermuscular septa separate the two muscles from the extensor digitorum longus and peroneus tertius in front and the soleus and flexor hallucis longus behind. Above the ankle the muscles are continued into tendons which pass in company behind the external malleolus, then forwards under cover of the external annular ligament along the outer surface of the heel. The tendon of the brevis, which lies above the other, reaches the base of the fifth metatarsal, that of the longus is continued across the sole to the first metatarsal bone. A common synovial membrane invests both tendons behind the malleolus and under cover of the annular ligament, but splits into two where the tendons begin to separate. A second synovial membrane surrounds the tendon of the longus in the sole. The muscles are supplied by the musculo-cutaneous nerve.

The **peroneus longus** arises from the external surface of the head and the upper two-thirds of the outer surface of the shaft of the fibula; additional fibres spring from the intermuscular septa in front and behind, and from the external tuberosity of the tibia above. In the lower part of the leg it narrows to a tendon which passes behind the outer malleolus and forwards, first under cover of the external annular ligament, then along the outer surface of the calcaneum to the cuboid, in the groove of which bone it sweeps forwards and inwards into the sole. It is inserted into the tuberosity of the first metatarsal bone and the adjoining part of the internal cuneiform bone. In crossing the sole the tendon lies in contact with the bones, and is covered by a fibrous investment from the long plantar ligament. A sesamoid bone is sometimes found in the portion of the tendon which lies in the groove of the cuboid.

The **peroneus brevis** arises from the middle two-fourths of the outer surface of the shaft of the fibula; additional fibres spring from the intermuscular septa in front and behind. Above the ankle it narrows to a tendon which passes behind the external malleolus, and is continued forwards, along the outer surface of the calcaneum and cuboid to the tuberosity of the fifth metatarsal bone, where it is inserted. Frequently the tendon sends a slip to the extensor tendon of the little toe. In passing round the malleolus the tendon lies in front of and afterwards above that of the peroneus longus.

Variations of the muscles of the external region of the leg. The two peronei are sometimes partly united with one another. An additional muscle, the peroneus quartus, is sometimes found springing from the

fibula, behind the peroneus brevis, and passing to insertion on the calcaneum or cuboid. Another accessory slip, the peroneus quinti digiti,

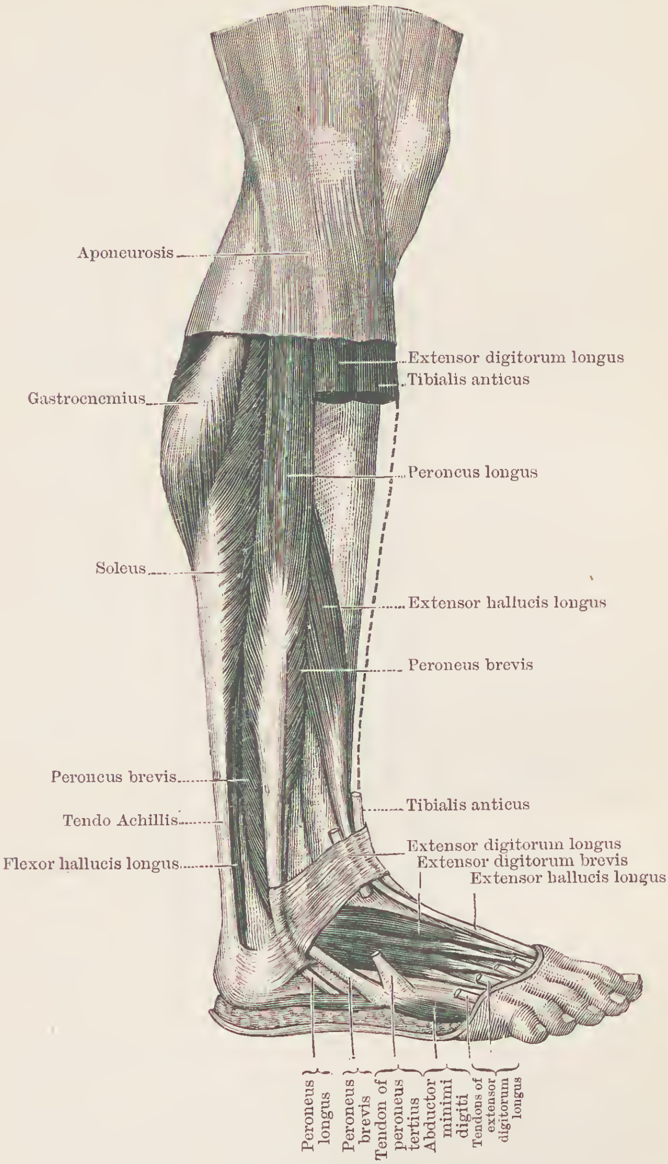


Fig. 257.—Outer Region of Leg. (L. Testut.)

is occasionally found passing from the fibula, below the peroneus brevis, to the extensor tendon of the little toe; when present it takes the place of the slip detached from the tendon of the peroneus brevis.

ANTERIOR REGION OF THE LEG.

The muscles of the anterior region of the leg are the tibialis anticus, the extensor hallucis longus, the extensor digitorum pedis longus, and the peroneus tertius; but the last-mentioned is small, and is regarded as a portion of the extensor digitorum longus. In the upper fourth of the

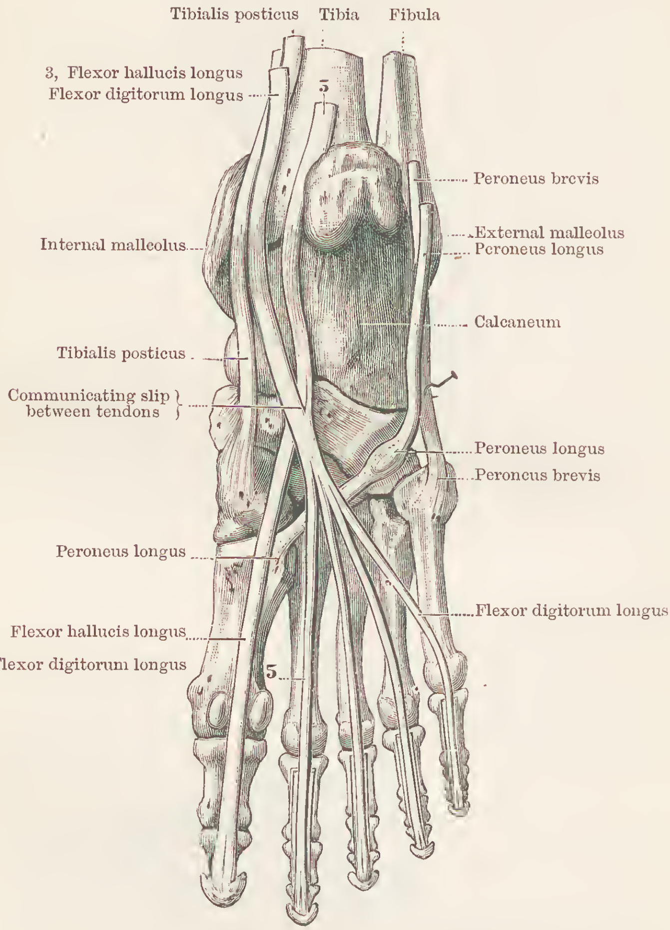


Fig. 258.—Insertions of Tendons in the Sole, semi-diagrammatic. (L. Testut.)

leg the tibialis anticus, the most internal of the group, lies in contact with the extensor digitorum longus, their fibres being separated only by an intermuscular septum. Lower down, the extensor hallucis longus intervenes between them; but this muscle, smaller than those between which it is placed, is at first overlapped and concealed by them, and only becomes apparent on the surface, between their tendons, in the lower third of the leg. An intermuscular septum on the outer side of the group

separates the extensor digitorum longus and peroneus tertius from the peroneus longus and peroneus brevis.

Above the ankle the different muscles of the group narrow to tendons, that of the long extensor of the toes subdividing into four, which pass behind the anterior annular ligament to reach the dorsum of the foot. In passing behind the ligament the tendons maintain their relative positions to one another, and the two more internal are contained each in a special compartment, and those of the long extensor of the toes and peroneus tertius in a fibrous loop which forms the outer part of the ligament. The fibrous sheaths are lined by synovial membranes which are reflected upwards and downwards for a little distance upon the tendons. On the dorsum of the foot the tendons lie in a plane superficial to the short extensor of the toes; the tibialis anticus and peroneus tertius pass to the inner and outer sides respectively, the others are continued forwards to the extremities of the toes.

The anterior tibial artery is covered by the fleshy part of the tibialis anticus, and is crossed in the vicinity of the ankle by the tendon of the extensor hallucis longus. The anterior tibial nerve, which accompanies the artery, supplies all the muscles of the group.

The **tibialis anticus** (*tibialis anterior*) arises from the upper two-thirds of the outer surface of the shaft of the tibia extending to the base of the outer tuberosity, and from a narrow area of the adjoining interosseous membrane; fibres also spring from the investing fascia and the short septum on the outer side of the muscle. The area of origin from the bone is much broader above than below, where it narrows to a line close to the interosseous membrane. It is inserted into the anterior and inner part of the base of the internal cuneiform bone and the adjoining ridge of the first metatarsal bone. Its tendon becomes free from muscular fibres in the lower third of the leg; near its insertion it is somewhat expanded, and a small bursa lies beneath it.

The **extensor hallucis longus**, a very narrow muscle, is somewhat obliquely placed at its origin. It springs from the middle third of the anterior portion of the inner surface of the fibula and the adjacent interosseous membrane, and below in the upper part of the lower third of the leg from the interosseous membrane alone. Its tendon forms on its anterior margin, and becomes free about the level of the ankle. It is inserted after giving off lateral expansions which cover the first metatarso-phalangeal joint into the dorsal surface of the terminal phalanx of the great toe at its base.

The **extensor digitorum pedis longus** has an exceedingly narrow origin which extends along the upper two-thirds of the anterior portion of the inner surface of the fibula, and reaches upwards in front of the head of the bone to the external tuberosity of the tibia; in addition, many of its fibres spring from the intermuscular septum on its outer side, and a few from the short septum on its inner side; others spring from the upper part of the interosseous membrane. The tendon forms on the anterior

edge of the muscle, becomes free above the ankle, and almost immediately divides into four portions, which proceed towards the four outer toes. Each tendon, on reaching the dorsum of the first phalanx, spreads after the manner of the tendons of insertion of the common extensor of the

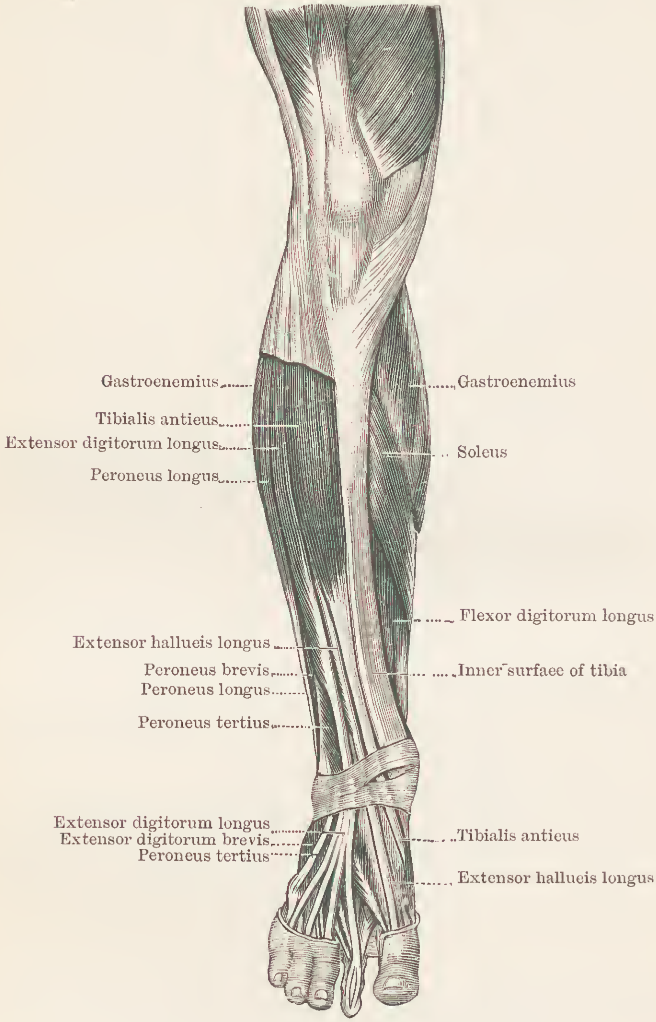


Fig. 259.—Anterior Region of Leg. (L. Testut.)

fingers into an expansion from which three slips are continued, the median to the base of the second phalanx, the two lateral, after re-uniting, to the base of the third. The tendinous expansions are joined by the tendons of the lumbricales and interosseous muscles, and those of the three inner of the toes into which the muscle is inserted by the tendons of the short extensor muscle.

The **peroneus tertius**, taking origin in the upper part of the lower third of the leg, springs from the anterior portion of the inner surface of the fibula, the adjacent interosseous membrane, and the intermuscular septum on its outer side. Its tendon, broadening near its extremity, is inserted into the upper surface of the base of the fifth metatarsal bone and gives a slip to the base of the fourth.

Variations of the muscles of the anterior region of the leg. The peroneus tertius is often wanting. In connection with the others additional slips of insertion are frequently found. The tibialis anticus may be partly inserted into the fascia of the dorsum of the foot, the synovial membrane of the ankle, or the neck of the astragalus. The extensor hallucis longus occasionally detaches a tendinous slip to the first metatarsal bone, and a small accessory muscle, an extensor primi internodii hallucis has been observed. The tendons of the extensor digitorum longus occasionally detach slips to the corresponding metatarsal bones.

POSTERIOR REGION OF THE LEG.

The muscles of this region are arranged in two groups, superficial and deep, between which the posterior tibial artery and nerve descend towards the foot.

The **superficial group** is formed by the gastrocnemius, soleus, and plantaris, all of which are inserted into the basal portion of the os calcis. The gastrocnemius and soleus, large muscles, the first taking origin above and the other below the knee-joint, descend in company, the one behind the other, and together form the prominence of the calf of the leg. Their tendons of insertion are incorporated together to form the tendo Achillis. The plantaris, a small muscular belly with a long slender tendon, lies between the other two.

Another muscle, the popliteus, although, from its position in front of the vessels and nerves, entitled to be ranked with the deep group, is more conveniently treated along with those of the superficial group. It is small and confined to the upper part of the leg.

The internal popliteal nerve supplies the gastrocnemius, plantaris, and popliteus muscles. The soleus is partly supplied by the internal popliteal and partly by the posterior tibial nerve.

The **gastrocnemius** is formed of two fleshy bellies which spring separately from the back of the femur, and are united about the middle of the leg in a common tendon. The inner head, tendinous internally, fleshy externally, takes origin along an oblique line, of about an inch in length, which lies close above the posterior extremity of the articular surface of the internal condyle. The outer head, tendinous, arises along a somewhat shorter line at the posterior margin of the outer surface of the external condyle, extending almost vertically upwards from a depression above the popliteal groove. The fleshy bellies on the posterior surface of which

the tendons of origin are prolonged for a little distance approach one another in the upper third of the leg, limiting the popliteal space, and

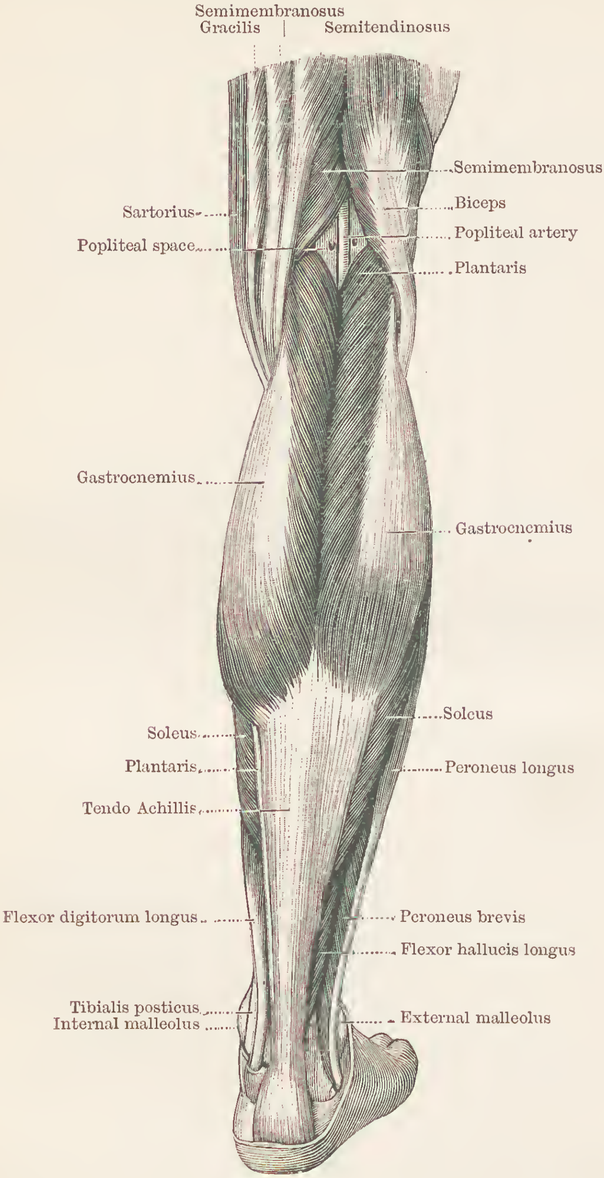


Fig. 260.—Posterior Region of Leg, superficial layer. (L. Testut.)

their edges thereafter, although separated superficially by a groove, are united more deeply by a tendinous raphe. The tendon of insertion, thin and membranous, clothes the greater part of the deep surface, and after

receiving all the muscular fibres becomes incorporated with the tendon of the soleus to form the *tendo Achillis.* The inner belly is broader and extends a little further down than the outer. Underneath the inner head lies a bursa which communicates frequently with the cavity of the joint, and

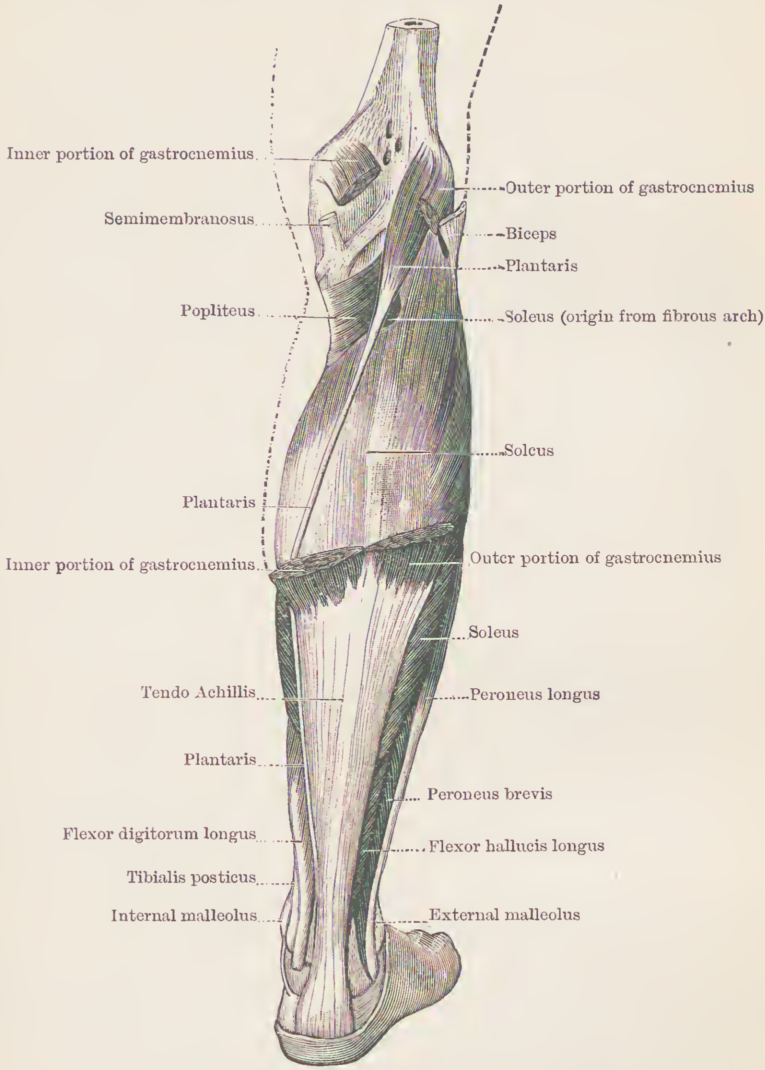


FIG. 261.—POSTERIOR REGION OF THE LEG (the gastrocnemius divided). (L. Testut.)

between it and the semimembranosus tendon another bursa is usually found. The outer head frequently contains a sesamoid bone.

The **soleus,** not so conspicuously divided into lateral portions as the gastrocnemius, forms a large but short-fibred muscle. It is attached above, externally to the posterior surface of the head and upper third of the

shaft of the fibula, and internally to the popliteal line, and below it to the inner margin of the tibia for two or three inches; between the upper ends of the bony attachments fibres, intermediate in position, spring from a fibrous arch which crosses the large vessels and nerve. The muscular belly descends on the tendo Achillis to within a short distance of the heel.

The fibres of the muscle which are short and oblique pass between three tendinous structures—one a median vertical raphe, the other two broad sheets of longitudinally running fibres, one almost entirely concealed in the substance of the muscle with its edges appearing on the deep surface, the other covering the superficial surface. The median raphe is continued up from the tendo Achillis; it is strong and complete below, but above it narrows and is confined to the deep part of the thickness of the muscle. The posterior broad or superficial tendon is likewise continued from the tendo Achillis, and becomes finer near the upper end of the muscle. The anterior broad or concealed tendon is stronger above than below, and splits into two as it descends into the region where the median raphe is complete; from both its surfaces muscular fibres spring, so that it is to a large extent hidden within the muscular substance. Those from its posterior surface, forming the great mass, and the edges of the muscle pass chiefly into the posterior broad tendon; those from its anterior surface, much fewer in number, and not occupying the whole extent of the surface, but leaving a marginal area bare on each side, are directed downwards and forwards towards the central raphe.

Fig. 262.—The Soleus, deep surface.

The **tendo Achillis** (*tendo calcaneus*), the strongest tendon in the body, extends through the lower half of the leg. It is formed by the broad but thin tendon of the gastrocnemius becoming incorporated with the posterior surface of the soleus tendon. It becomes narrower and thicker as it descends, and then, expanding slightly, is inserted into the lower part of the posterior surface of the os calcis. A bursa intervenes between the upper part of the surface and the tendon.

The **plantaris**, a small muscular belly of about three inches in length, continued into a long slender tendon, is, at its origin, almost completely covered by the outer head of the gastrocnemius. It springs by fleshy fibres from the lower extremity of the external supracondylar ridge of the femur, and from the adjacent portion of the capsular ligament of the knee. The tendon, passing downwards and inwards in front of the gastrocnemius, reaches the inner margin of the tendo Achillis, and in close contact therewith is inserted into the basal portion of the os calcis.

The **popliteus**, small, thin, and triangular, is closely applied to the bones and ligaments at the back of the knee. It springs from the femur

within the capsule of the joint and under cover of the external lateral ligament, from the anterior extremity and upper margin of the popliteal groove, by a narrow tendon which, descending with an inward direction, grooves the external semilunar cartilage and pierces the posterior ligament. The muscular fibres, reinforced by a few from the posterior part of the capsule, spread out and are inserted into the whole of the triangular area of the shaft of the tibia above the popliteal line.

The deep group. The muscles of the deep group, with the exception of the popliteus, which has been already described, are the tibialis posticus, the flexor hallucis longus, and the flexor digitorum pedis longus. They are continued by tendons which pass round the internal malleolus, under cover of the internal annular ligament, into the sole. At the origin the tibialis posticus lies between the other two, springing from the tibia and fibula and the interosseous membrane; the flexor hallucis longus on the outer side springs from the fibula, and the flexor digitorum longus on the inner side takes origin chiefly from the tibia. A horizontally stretched intermuscular septum separates the muscles of this group from the soleus and detaches partitions which separate the tibialis posticus from its neighbouring muscles. A vertical septum at the outer side intervenes between the flexor hallucis longus and the peroneus longus and brevis. The posterior tibial vessels lie upon the surface of the tibialis posticus, and the accompanying posterior tibial nerve supplies the muscles.

A little distance above the ankle a change takes place in the relative position of the muscles. The tendon of the tibialis posticus passes forwards and inwards in front of the flexor digitorum longus. In passing round the internal malleolus, under cover of the internal annular ligament, the tendons are confined by septa in osteo-fibrous canals which are lined by synovial membrane; the tendon of the tibialis posticus is anterior in position, that of the flexor digitorum longus immediately behind it, while that of the flexor hallucis longus is the most posterior; the vessels and nerve lie between the two last-mentioned tendons, but in a plane slightly superficial to them.

In the sole the tendons are covered by the superficial layer of muscles. That of the tibialis posticus, close to the bones, passes forwards on the inner side to the scaphoid. The tendon of the flexor hallucis longus is directed forwards to the great toe, on its way crossing above the tendon of the long flexor of the toes and detaching a slip to it. The tendon of the flexor longus digitorum, passing forwards and outwards, to be inserted into the four outer toes, receives from behind, about the middle of the foot, the insertion of the flexor accessorius, and divides immediately thereafter into four portions, from which, close to the point of division, the lumbricales muscles spring.

The **tibialis posticus** (*tibialis posterior*) springs from the upper three-fourths of the shaft of the fibula, occupying at its origin the whole of

the posterior area of the inner surface, from the upper half of the outer part of the posterior surface of the tibia, and from the inter-osseous membrane. Fibres also take origin from the intermuscular

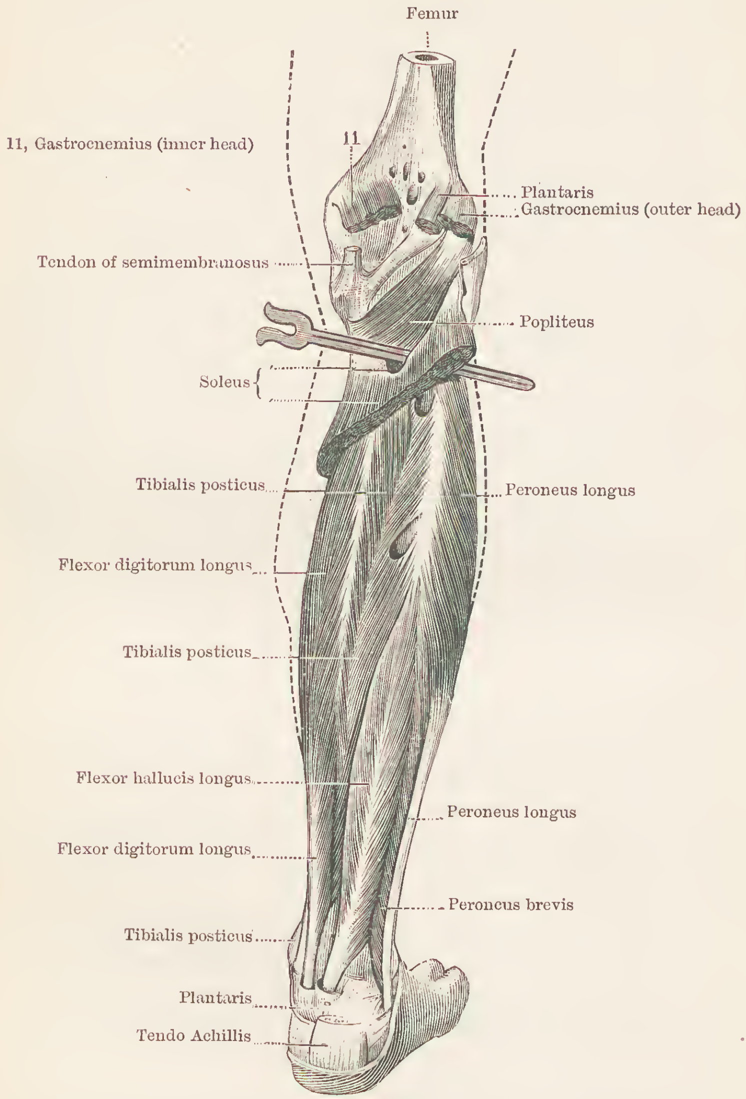


FIG. 263.—POSTERIOR REGION OF LEG, deep group of muscles. (L. Testut.)

septum on the surface of the muscle. The tendon forms on the inner border of the muscle and becomes free from muscular fibres a little above the ankle. It is inserted into the tuberosity of the scaphoid bone, but detaches slips to the internal cuneiform bone, the sustentaculum tali,

and the ligaments of the sole. Near the insertion a sesamoid bone lies in the tendon.

The **flexor hallucis longus** takes origin from the lower two-thirds of the posterior surface of the fibula; fibres also spring from the layer of deep fascia which covers the muscle. The tendon forms on the inner edge of the muscle, becomes free at the level of the ankle, and in passing round the malleolus grooves the back of the astragalus, and the sustentaculum tali. On its way forwards in the sole it crosses above and detaches a slip to the tendon of the long flexor of the toes. It enters a fibrous sheath on the first phalanx of the great toe, and is finally inserted into the base of the second phalanx on its plantar surface.

The **flexor digitorum pedis longus** arises from the inner part of the posterior surface of the tibia, and occupies at its origin a region corresponding to the middle two-fourths of the shaft; fibres also spring at its outer border from the intermuscular septum, which covers the tibialis posticus, and which, arching over the tendon of that muscle, is connected below with the interosseous membrane and the fibula. The tendon becomes free from muscular fibres at the upper border of the internal annular ligament; in passing forwards and outwards in the sole it is connected with that of the flexor longus hallucis, and receives the insertion of the flexor accessorius. Immediately thereafter it divides into four portions, which, after giving origin to the lumbricales, are continued to the four outer toes, where they are inserted into the terminal phalanges. Each tendon as it passes forwards in the toe pierces a tendon of the superficial flexor, and the tendons in each toe are surrounded by a fibrous and synovial sheath similar in all respects to that which in the finger surrounds the flexor tendons.

The **flexor accessorius** is closely associated with the tendon of the flexor digitorum longus, and like it is covered by the superficial muscles of the sole. It arises from the lower part of the calcaneum by two heads, the inner broad and fleshy from the anterior tubercle and a portion of the area behind it, the outer narrow and tendinous from the base of the external tubercle. The muscular belly is inserted, about half-way forwards in the sole, into the outer margin and the upper surface of the tendon of the long flexor of the toes.

The **lumbricales,** four fleshy slips, take origin from the tendons of the flexor digitorum longus, close to their point of separation. The most internal springs from the inner side of the tendon for the second toe, each of the others from the two tendons between which it is placed. They are inserted tendinously into the four outer toes, each tendon passing along the inner side and reaching the tendinous expansion on the dorsal surface of the first phalanx.

Variations of the muscles of the posterior region of the leg. The plantaris is frequently absent. As a rare occurrence, absence of the gastrocnemius has been noted. An accessory head of the gastrocnemius has been

found either on the inner or outer side arising from the fascia, the tendons round the joint, or the lower part of the femur; the soleus and plantaris in like manner occasionally receive additional slips of origin. The soleus has been found partially or wholly inserted separately into the calcaneum. In connection with the popliteus an additional slip is frequently noticed passing from the head of the fibula to the oblique line of the tibia (the peroneo-tibial muscle of Grüber). Among the deep group two small

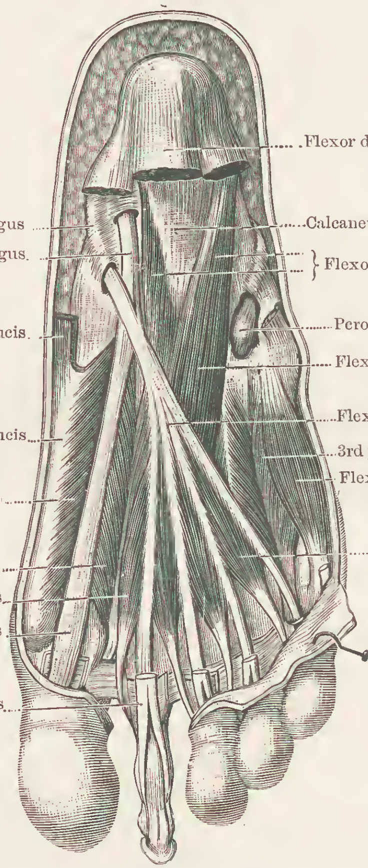


FIG. 264.—SECOND LAYER OF THE MUSCLES OF THE SOLE. (L. Testut.)

occasional muscles have been described—a tensor of the capsule of the ankle-joint springing from the lower part of the tibia, and a peroneo-calcanean from the posterior surface of the external malleolus to the calcaneum.

THE SOLE.

The special muscles of the sole, along with the tendons of those of the deep group of the back of the leg and their associated muscles, form altogether four layers covered superficially, or on the plantar aspect, by

the plantar fascia. Two sets of vessels and nerves, the external and internal plantar, derived from the posterior tibial trunks which divide on entering the sole, pass forwards among the muscles supplying them and reaching the toes.

The muscles of the first layer, three in number, from within outwards the abductor hallucis, the flexor digitorum brevis, and the abductor minimi digiti, occupy the whole length of the sole, and are intimately connected

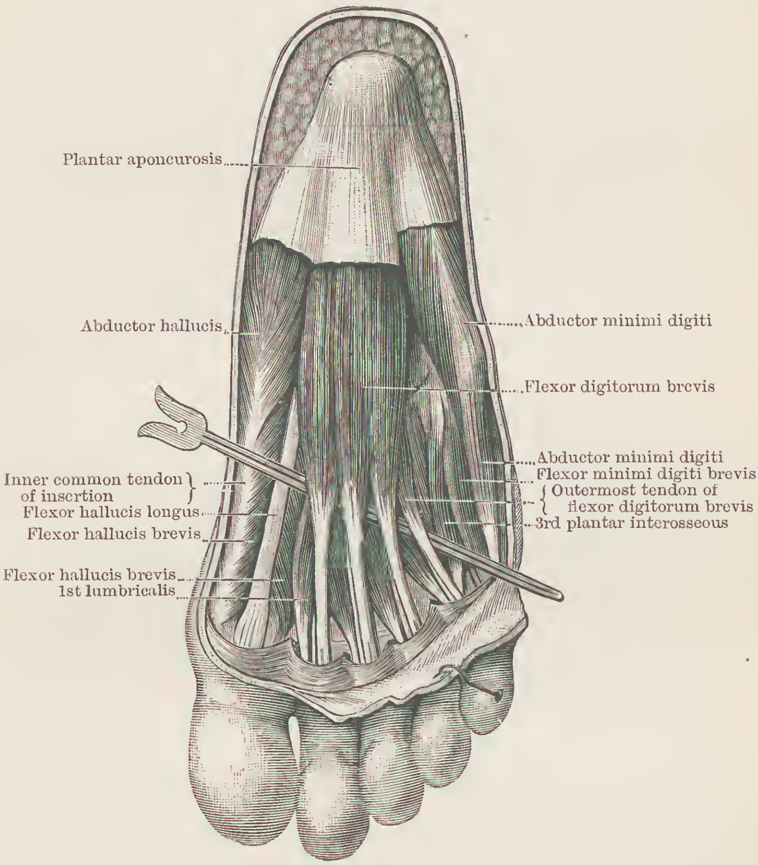


Fig. 265.—First Layer of the Muscles of the Sole. (L. Testut.)

with the plantar fascia. Two vertical septa of fascia, one on each side of the central muscle, separate the muscles of this layer from one another; and between the abductor hallucis and the short flexor of the toes the internal plantar nerve and artery pass forwards.

In the second layer are found the tendons of the long flexors of the toes and the associated muscles, the accessorius and lumbricales, all of which have been already described. Between this layer and the first the

external plantar artery and nerve pass forwards and outwards as far as the base of the fifth metatarsal bone.

The third layer is formed of short muscles specially connected with the great and small toes. They are confined to the anterior part of the foot. Those passing to the great toe, three in number, are in order from within outwards, the flexor hallucis brevis, the adductor hallucis, and the transversus pedis. At some little distance from these, underlying the fifth metatarsal bone, is the flexor minimi digiti brevis.

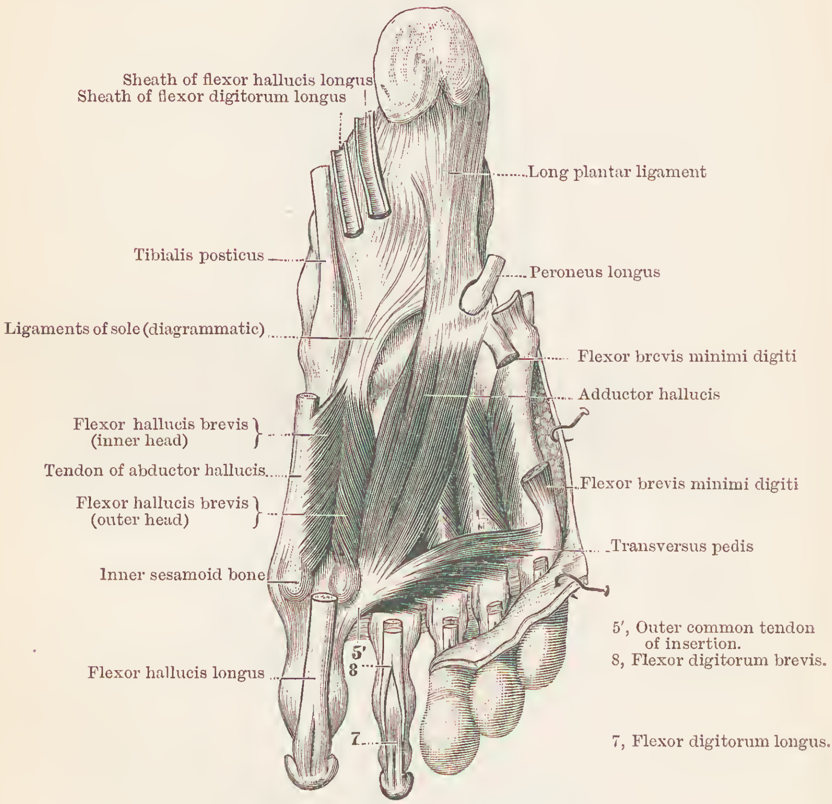


Fig. 266.—Third Layer of the Muscles of the Sole. (L. Testut.)

The interosseous muscles form the fourth layer. They occupy the spaces between the metatarsal bones and are seven in number, as in the hand, four dorsal and three plantar in position. Between the interosseous muscles and the short muscles of the great toe, the external plantar artery and the accompanying deep branch of nerve bend inwards in the sole, passing from the base of the fifth metatarsal bone towards the first interosseous space. Further back in the sole the tendons of the peroneus longus and tibialis posticus lie close to the bones.

The supply of the muscles of the foot is divided between the external

and internal plantar nerves. The internal plantar supplies the flexor digitorum brevis, the abductor hallucis, the flexor hallucis brevis, and the innermost lumbricalis. All the other muscles in the sole are supplied by the external plantar.

The **flexor brevis digitorum** occupies the middle of the sole. It is very narrow behind, but broadens considerably as it passes forwards. It springs from the internal calcaneal tubercle, and receives many fibres from the plantar fascia, which covers it and detaches a septum on either side. Opposite the bases of the metatarsal bones it divides into two portions, each of which almost immediately gives origin to two tendons. The tendons pass to the four outer toes. Each, after entering a sheath, is perforated by a tendon of the long flexor, and is inserted into the second phalanx, the whole arrangement being similar to that already described in connection with the flexor muscles of the fingers.

The **abductor hallucis** springs from the inner calcaneal tubercle, the internal annular ligament, and the investing plantar fascia, and receives in addition, in most cases, fibres from the scaphoid and internal cuneiform bones. Becoming tendinous behind the ball of the great toe, it is inserted in conjunction with the inner portion of the flexor brevis hallucis into the tuberosity at the inner side of the base of the first phalanx.

The **flexor hallucis brevis** springs from the calcaneo-cuboid and naviculo-cuneiform ligaments in close connection with the insertion of the tibialis posticus. The muscular belly divides into two portions, each of which is continued forwards into a tendon. The inner tendon conjoined with that of the abductor is inserted into the internal basal tuberosity of the first phalanx; the outer tendon, along with the adductor and transversus pedis, into the external tuberosity. A large sesamoid bone lies in each tendon of insertion.

The **adductor hallucis** (*addŭctor obliquus*) arises from the long plantar ligament and the basal extremities of the second and third metatarsal bones. It is inserted with the outer portion of the flexor brevis.

The **transversus pedis** (*adductor transversus*), very small, passing almost directly inwards, and placed close to the bones, springs by slips from the metatarso-phalangeal ligaments of the second, third, and fourth toes. It is inserted with the adductor hallucis. The muscle is covered by the flexor tendons, and crossed superficially by the digital nerves, but the digital arteries of the second and third interspaces pass forward on its dorsal surface.

The **abductor minimi digiti**, very broad behind, arises from the under surface of the os calcis, immediately in front of the external and internal tubercles, and from the investing plantar fascia. Becoming narrow and tendinous as it passes forwards, it is inserted into the outer side of the base of the first phalanx of the fifth toe.

The **flexor minimi digiti brevis**, a small fleshy slip, arises from the

under surface of the base of the fifth metatarsal bone, and the sheath of the peroneus longus. It is inserted with the abductor minimi digiti.

The interosseous muscles. The arrangement of these muscles is very similar to that of the corresponding muscles in the hand, but differs from it in this respect that in the foot the muscles are grouped round the second digit instead of the third, as in the hand. Springing from the metatarsal bones they are inserted by tendons, which cross the metatarso-phalangeal joints, partly into the basal portions of the phalanges of the first row, partly into the expansions of the extensor tendons.

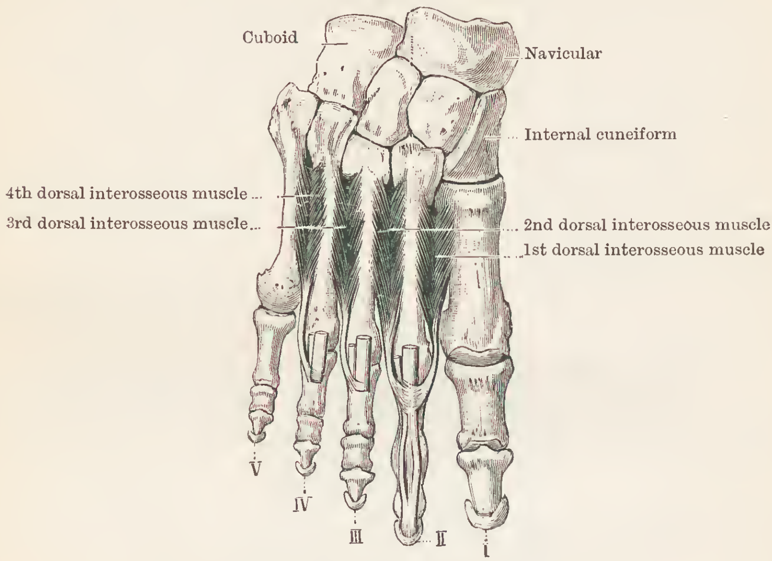


FIG. 267.—THE DORSAL INTEROSSEOUS MUSCLES. (L. Testut.)

The four dorsal muscles. Each springs from the sides of both the bones between which it is placed; but while in most cases the origins extend along nearly the whole length of the metatarsal bones, the inner head of the first muscle is connected with the base only of the first metatarsal bone. The first two are inserted into the second digit. The third and fourth belong to the outer sides respectively of the third and fourth digits.

The three plantar muscles act cn the three outer toes, and each is placed on the inner side of the digit to which it belongs. Each arises from but one metatarsal bone, that of the digit upon which the muscle acts, but all derive additional fibres from the sheath of the peroneus longus muscle.

DORSUM OF THE FOOT.

In addition to the tendons of the long muscles already described, one special muscle is found upon the dorsum of the foot.

The **extensor brevis digitorum** takes origin from the anterior part of the upper and outer surfaces of the os calcis, and from the anterior annular ligament. It divides into four tendons, which pass to the four inner toes. The tendon belonging to the great toe is inserted into the dorsal surface of the first phalanx. Those of the second, third, and fourth digits join from the outer side the corresponding tendons of the long extensor. The

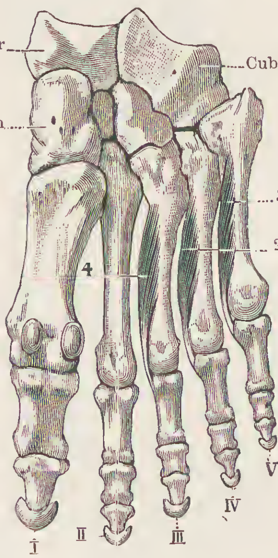


Fig. 268.—The Plantar Interosseous Muscles. (L. Testut.)

muscle is crossed by the tendons of the long extensor and peroneus tertius. Its innermost tendon crosses the dorsal artery of the foot. It is supplied by the external branch of the anterior tibial nerve.

Actions of the Muscles of the Leg and Foot.

The *popliteus* acts upon the knee-joint alone. In full extension of the joint the muscle acts as a rotator outwards of the femur, or inwards of the tibia, its tendon occupying a groove which crosses the lower lip of the popliteal groove of the femur. In this action the muscle assists to initiate flexion by undoing the lock between the articular surfaces of the joint. In addition, it is probable, on the other hand, as was held by Goodsir, and as may be observed during manipulation of the joint in the dead body, that in the later stages of flexion the muscular fibres are again fully stretched, owing to the upward rotation of the anterior part of the

external condyle during the movement. Acting in this position the muscle would assist in the initial stages of extension, its tendon occupying the popliteal groove of the femur.[1]

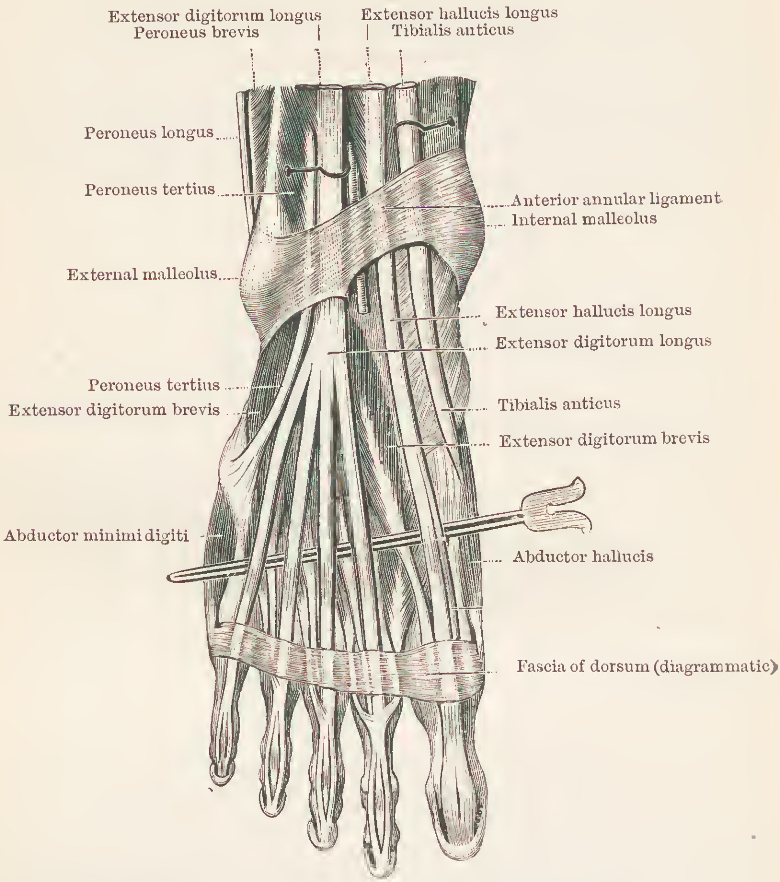


Fig. 269.—Muscle and Tendons of the Dorsum of the Foot. (L. Testut.)

The *gastrocnemius* acts upon both knee and ankle, producing flexion of the former or extension of the latter, according as the one or other extremity of the muscle is maintained in a fixed position. It undergoes no change of length in the passage from standing erect on tip-toe to extreme flexion of the knee and flexion of the ankle-joint, and may be held as acting ligamentously in all ordinary movements of flexion and extension of the limb. The *soleus* acts upon the ankle alone, assisted

[1] Goodsir taught that this was the special action of the popliteus, and that it undid the inward twist given to the outer condyle of the femur in extreme flexion (page 193). I prepared for him, at his desire, a dissection of the leg of the cat, showing that in that animal the popliteus extended the flexed joint to a very considerable extent.—J. C.

by the gastrocnemius, causing extension and raising the heel from the ground. On account of its great strength and the shortness and obliquity of its fibres, the muscle serves the purpose of a strong elastic ligament behind the ankle-joint, and plays an important part in supporting the joint in the erect position of the body. The form of club-foot known as *talipes equinus*, in which the heel is raised and the patient walks upon the toes, is due to the abnormal contraction of the muscles inserted by the tendo Achillis.

The *tibialis anticus* and *peroneus tertius* flex the ankle; the former also assists in inversion, the latter in eversion of the sole. The *extensor digitorum longus* and the *extensor hallucis longus*, after full extension of the digits, also take part in flexion of the ankle. *Talipes calcaneus*, in which the toes are extended and the ankle flexed, the patient walking upon the heel, is dependent on the muscles of the anterior region of the leg. The *tibialis posticus* inverts the sole and slightly extends the ankle. *Talipes varus*, in which the inner side of the foot is raised and the heel drawn up, is dependent on this muscle, with the frequent association of the tibialis anticus; the variety known as *equino-varus*, in which the heel is still further raised, depends upon the implication of the muscles inserted by the tendo Achillis. The *peroneus longus* and *brevis* extend the ankle and evert the sole. *Talipes valgus*, in which the outer side of the foot is raised, is dependent on these muscles, and when those of the anterior region are likewise involved, the variety *calcaneo-valgus* is produced. The *flexor digitorum longus*, after full flexion of the digits, or when the toes are fixed, assists in extension of the ankle; its action upon the toes is brought into the line of the foot by the *flexor accessorius*. The action of the other muscles of the foot is sufficiently indicated by the names which are applied to them.

FASCIA OF THE LEG AND FOOT.

The **deep fascia of the leg**, strong and resistant, is continuous over the popliteal space and on the inner side of the limb with the fascia lata. In the upper part of the leg it is strengthened by fibres from the tendons of the biceps, sartorius, gracilis, semitendinosus, and semimembranosus muscles. It is firmly fixed over the prominent parts of the bones, being thus attached to the head of the fibula, the external tuberosity of the tibia, the anterior border, the whole inner surface, and the posterior border of that bone, and the internal and external malleoli. From its deep surface fibrous septa pass to the anterior and external borders of the fibula, separating the peroneus longus and brevis muscles from those in front and behind. Among the anterior muscles a short vertical septum, confined to the upper part of the leg, passes between the tibialis anticus and extensor digitorum longus; and among the posterior muscles a transverse septum, attached to the outer border of

the fibula and the posterior border of the tibia, separates the deep from the superficial group, and covers the vessels and nerve. The fascia affords attachment on its deep surface and its septa to many of the muscles of the leg.

The **anterior annular ligament** is formed by a thickening of the fascia at the level of the ankle-joint. It is shaped like the letter Y laid upon its side, the outer part representing the base of the letter, the inner portions the limbs. The outer part of the ligament forms a strong loop through which, wrapped in a common synovial sheath, the tendons of the long extensor of the toes and that of the peroneus tertius pass. The loop is attached externally to the upper surface of the os calcis, in front of the interosseous ligament, but some of its fibres are continuous with the lower part of the external annular ligament. From the inner extremity of the loop the limbs of the Y pass inwards. The upper, which is the stronger, is attached to the internal malleolus; the lower, passing over the border of the dorsum of the foot, becomes continuous with the lower part of the internal annular ligament. The tendons of the extensor of the great toe and the tibialis anticus pass, each surrounded by its own synovial sheath, in separate compartments, the former behind both bands, the latter through the upper and behind the lower. The anterior tibial artery and nerve sometimes accompany the tendon of the extensor of the great toe, but occasionally occupy a special fibrous and synovial sheath. A somewhat thickened band of fascia in the lower part of the leg, lying immediately above the anterior annular ligament, is sometimes described along with it. The synovial sheath of the tibialis anticus extends upwards behind this band.

The **internal annular ligament** is a thickened band of fascia, with ill-defined edges, stretching downwards and backwards from the internal malleolus to the inner margin of the tuberosity of the os calcis. Its lower part is continuous with the lower band of the anterior annular ligament, and gives origin to a large portion of the abductor hallucis muscle. On its deep surface pass, in separate sheaths, each lined by synovial membrane, the tendons of the tibialis posticus, flexor digitorum longus, and flexor hallucis longus. The sheaths of the two first mentioned lie close together, and occasionally communicate; the posterior tibial vessels and nerve occupy a sheath between the second and third, but lie in a plane slightly more superficial than that of the tendons.

The **external annular ligament**, from the point of the external malleolus, extends downwards and backwards to the lower portion of the outer surface of the calcaneum. The ligament covers the tendons of the peroneus longus and brevis, which, as they pass forwards on its deep surface, occupy a common synovial sheath. Continuous with the anterior margin of the ligament and with the outer extremity of the anterior annular ligament a couple of fibrous loops surround and separate from one another the two tendons.

Deep fascia of the sole. As in the hand, two layers of fascia are found—one, the plantar aponeurosis, superficial to the muscles; the other more deeply placed, covering and investing the interosseous muscles.

The plantar aponeurosis is divided into three regions—a central and two lateral, and along the lines of union between these intermuscular septa pass deeply into the sole. It is connected with the skin by numerous fibrous bands, and is perforated in many places for the passage of cutaneous vessels and nerves. The *central portion*, triangular in outline, is attached behind to the internal tubercle of the calcaneum. It is exceedingly strong and dense, and affords origin to many of the fibres of the superficial flexor of the toes. Posteriorly the fibres of the aponeurosis are parallel and directed forwards, but in the anterior part of the foot transverse fibres are added, and the whole structure spreading out becomes somewhat thinner. A little behind the digital clefts it divides into five slips which, passing towards the toes, divide and sink deeply to join the metatarso-phalangeal and vaginal ligaments, the whole arrangement being similar to that of the central portion of the palmar aponeurosis, with the exception that in the foot there are five digital slips, while in the hand there are only four. A superficial transverse ligament binds the slips together, and offsets are detached to the skin. The *external lateral portion* forms an exceedingly strong band stretched between the external calcaneal tubercle and the tuberosity of the fifth metatarsal bone. It invests the abductor minimi digiti, and is continuous round the border of the foot with the fascia of the dorsum. The *internal lateral portion*, thin and unimportant, is continuous with the internal annular ligament of the ankle. It invests the abductor hallucis, and is continuous round the margin of the sole with the fascia of the dorsum. The *intermuscular septa* separate the internal plantar vessels and nerves and the abductor and short flexor muscles of the great toe on the one hand, and the abductor minimi digiti on the other hand, from the central space of the foot which is occupied by the short flexor of the toes, the tendons of the long flexor with the lumbricales and accessorius, the tendon of the long flexor of the great toe, and the external plantar vessels and nerves. The septa are well marked behind, but much weaker in front.

The **interosseous fascia** is weak and unimportant, but its anterior edge is strengthened into a firm band, the *transverse metatarsal ligament*, which binds together the heads of the five metatarsal bones.

Deep fascia of the dorsum of the foot. The fascia of the dorsum is relatively unimportant. A thin layer, continued from the anterior annular ligament, surrounds the tendons and covers the short extensor muscle; more deeply, a thin layer covers the interosseous muscles and the metatarsal bones.

MUSCLES AND FASCIA OF THE HEAD AND NECK.

The **superficial fascia** of the head and neck presents little of importance. It forms a somewhat dense layer in the region of the scalp and the nape of the neck. In the lateral part of the neck the platysma myoides, a thin muscular sheet, lies in its substance.

The **platysma myoides** is a thin subcutaneous muscular sheet extending over the side and front of the neck. The fibres spring from the fascia over the clavicle and pass upwards and inwards towards the lower jaw into the fascia over which most of them are inserted, between the attachment of the masseter and the symphysis. A few of the most internal cross the middle line, those of the right side being generally in front. The most posterior fibres sweep over the inferior maxilla and reach the angle of the mouth, where they become blended with other muscles. The size of the muscle is very variable, and it frequently receives accessory slips which have been noted as springing in different cases from the upper costal cartilages, the thyroid cartilage, the mastoid process, and the cartilage of the ear. On the deep surface of the muscle lie the trunks of the superficial veins and nerves of the neck. It is supplied by the inframaxillary branch of the facial nerve, which effects a junction with the superficial cervical of the cervical plexus. It raises the skin of the neck and breast, draws down the angle of the mouth, and can also depress the lower jaw; it has been conjectured that in its contraction, by drawing apart the walls of the external jugular vein, it may assist, in laboured respiration, the return of the venous blood from the head. The platsyma is the representative in man of a subcutaneous muscular sheet much more largely developed in many of the lower animals.

SUPERFICIAL MUSCLES OF THE HEAD.

A number of small muscles which act upon the soft parts of the face and scalp are included in this group. For convenience of description they are usually subdivided into smaller groups according to their more immediate action upon the scalp, ear, eyebrows and eyelids, nose, and mouth; but it will be seen that many act at the same time on more than one of the parts named. In the expression of emotions, in which these muscles play an important part, muscles which belong to the different subsidiary groups are often called into action at once. For a detailed scientific examination of the action of the facial muscles in this respect the student is referred to the work of Duchenne (Paris, 1862), as the subject is too large to be treated of in a manual of this scope. As to the simple action of each individual muscle it will, in the great majority of cases, be recognized as evident from the description, and need not entail a separate statement. All the muscles of this group are supplied by the seventh or facial nerve.

The **epicranial aponeurosis** is a thin tendinous expansion which covers the greater part of the surface of the cranium, and is closely connected with the two thin muscular sheets which on each side constitute the occipito-frontalis muscle. Anteriorly it is attached to the frontal portions

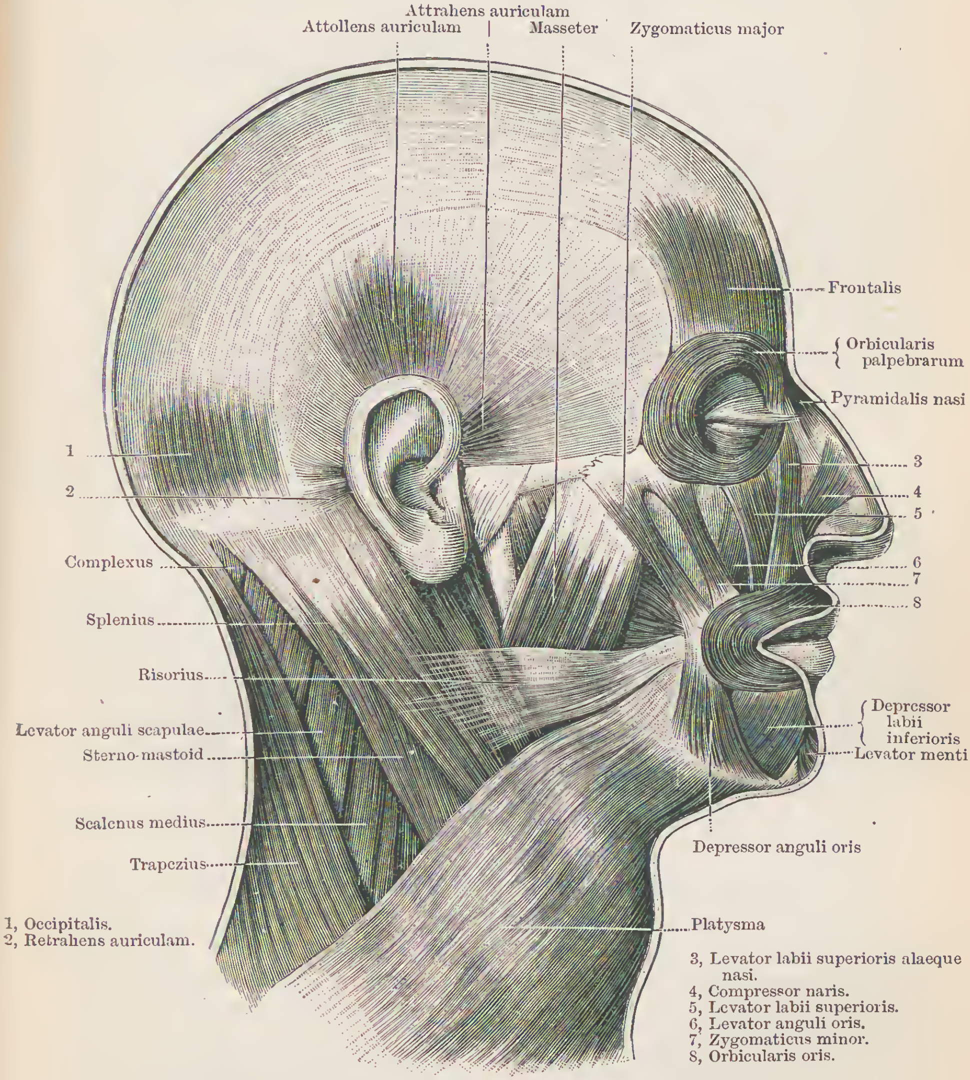


FIG. 270.—SUPERFICIAL MUSCLES OF THE HEAD. (L. Testut.)

of the muscles, posteriorly to the superior curved line of the occipital bone and to the occipital portions of the muscles. At the sides it degenerates into a thin tissue which overlies the temporal aponeurosis and gives origin to two of the auricular muscles. It is closely connected with the skin by firm tissue, containing fat in its meshes, and it lies upon the epicranial

periosteum, being separated only by a delicate tissue devoid of fat and allowing free gliding movement.

The **occipito-frontalis** muscle is formed of two portions, an anterior and posterior, connected with one another by the intervening epicranial aponeurosis.

The *occipital portion* (*occipitalis*) arises from the outer two-thirds of the superior curved line of the occipital bone, and occasionally to a small extent from the adjoining portion of the temporal bone. Its fibres, between one and two inches in length, pass into the epicranial aponeurosis.

The *frontal portion* (*frontalis*), larger and paler than the occipitalis, rises in a convex line from the epicranial aponeurosis some distance in front of the coronal suture. The fibres terminate in the subcutaneous tissue of the root of the nose and of the eyebrows. The muscles of opposite sides converge as they descend, and finally come into contact with one another. By the action of these muscles the scalp is drawn forwards and backwards, the eyebrows elevated, and the skin of the forehead thrown into transverse lines. In most cases they are only partially under the control of the will. They present frequent variations in the extent of their development.

The **attollens auriculam** (*auricularis superior*), a thin fan-shaped sheet of fibres, rises from the lateral portion of the epicranial aponeurosis. It is inserted into the upper part of the auricle in the region of the anterior part of the helix and antihelix.

The **attrahens auriculam** (*auricularis anterior*), a small thin bundle hardly separate from the anterior edge of the attollens, passes from the epicranial aponeurosis to the auricle in the region of the anterior part of the helix.

The **retrahens auriculam** (*auricularis posterior*) consists of two or three small bundles of fibres passing from the mastoid process to the auricle in the region of the posterior part of the concha.

In most cases the auricular muscles are not under the direct control of the will.

The **orbicularis palpebrarum** is a thin sheet of muscular fibres covering the surface of and surrounding the eyelids. The *central or palpebral portion* takes origin from the tendo palpebrarum or *internal tarsal ligament,* a narrow band about one-sixth of an inch in length, springing from the nasal process of the superior maxilla, and extending outwards in front of the lachrymal groove. The fibres, which are pale and thin, lie upon the surface of the tarsal membranes in the lids, and are connected externally with the *external tarsal ligament*, a less defined band than the internal, attached to the malar bone.

The *peripheral portion* of the muscle, much broader than the central and formed of coarser bundles of fibres, is variable in size and largely blended at its margins with other muscles. It springs from the basal portion of the internal tarsal ligament, the internal orbital process of the

frontal, and the nasal process of the superior maxillary bone. The fibres form a set of loops between the upper and lower attachments.

The **tensor tarsi**, or muscle of Horner, is a deep slip of the orbicularis lying behind the lachrymal sac. It springs from the ridge of the lach-

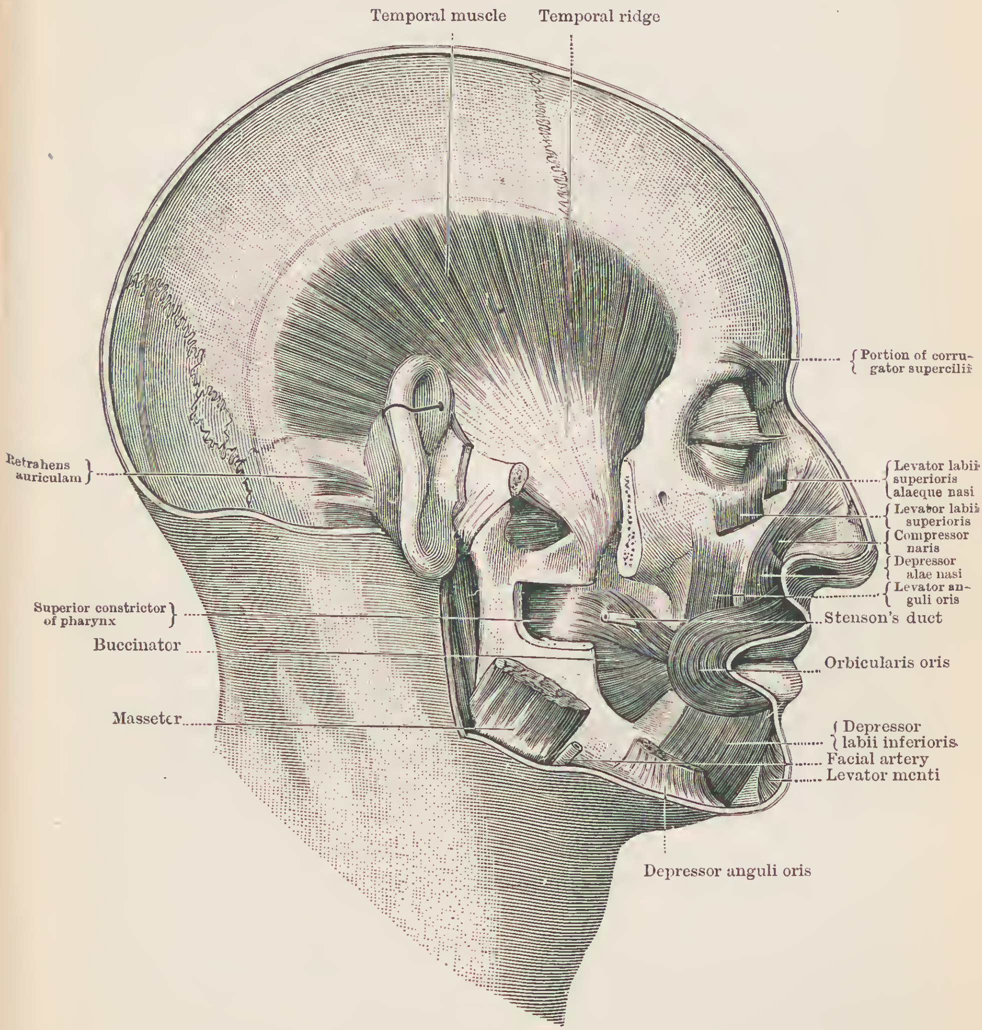


FIG. 271.—THE DEEPER MUSCLES OF THE HEAD. (L. Testut.)

rymal bone, and passes outwards to the marginal bundles of the palpebral portion of the muscle, dividing into two slips as it goes.

The **corrugator supercilii**. From the inner end of the superciliary ridge, and from the nasal process of the superior maxilla, a number of fibres spread upwards and outwards. They are closely associated with the frontalis muscle, on the deep surface of which they can be dis-

played when it is reflected with the skin. The upper and inner fibres are directed towards the frontal eminence; the lower and outer fibres pass outwards to the middle of the margin of the orbit.

The orbicularis closes the lids, draws down and smooths the skin of the forehead, and elevates that of the cheek. The palpebral portion, while closing the lids, probably presses against the wall of the lachrymal sac and canaliculi, causing the tears to enter when pressure ceases. The tensor tarsi assists in the compression of the sac and forces the tears along the duct. The whole set of fibres described as corrugator supercilii draws the eyebrows and the skin of the region beneath the frontal eminence downwards and inwards. When the corrugator and frontalis act together rectangular furrows are produced, the inner portion of the eyebrow is raised while the outer portion is depressed, and the transverse furrows of the outer part of the forehead which the occipitalis acting alone would produce are obliterated.

The **compressor naris**, thin and triangular, arises under cover of the elevator of the upper lip, from the superior maxillary bone between the canine fossa and the nasal margin. It spreads over the bridge of the nose into a subcutaneous aponeurosis common to it and its fellow of the opposite side.

The **pyramidalis nasi** consists of a few fibres prolonged downwards from the inner part of the frontalis, to terminate in the aponeurotic expansion of the compressor naris.

The **levator labii superioris alaeque nasi**, pointed at its origin and broadening below, springs from the nasal process of the superior maxilla, and is partly inserted into the ala of the nose, and partly blended with the orbicular muscle of the lips. In its descent it crosses the compressor naris.

The **depressor alae nasi** is a small irregular bundle of fibres closely connected with the compressor naris, passing from the incisor fossa of the superior maxilla and the skin of the lip, partly to the ala and partly to the septum of the nose.

The **dilatatores naris**, anterior and posterior, are two small indistinct slips passing from the cartilage of the nose to the skin at the lateral margin of the nostril.

Muscles of the lips. A number of muscles radiate towards the margins of the mouth, where their fibres becoming blended form an elliptical sheet, the orbicularis oris, which surrounds the aperture.

The **levator labii superioris**, four-sided in outline, arises immediately below the margin of the orbit and above the infra-orbital foramen. Its fibres, passing among those of the orbicularis oris, are inserted into the skin of the upper lip.

The **zygomaticus minor**, a small variable slip, passes from the anterior part of the malar bone to the skin of the lip. At its upper end it is closely associated with the orbicularis muscle of the eyelids, at its lower with the elevator of the upper lip.

The **zygomaticus major** springs from the outer part of the malar bone. Below it blends with the orbicularis, and is inserted into the skin at the angle of the mouth.

The **levator anguli oris** arises under cover of the elevator of the upper lip, from the canine fossa of the superior maxilla. It passes downwards to the angle of the mouth, its fibres being partly attached to the skin and partly continued into the lower part of the orbicularis.

The **risorius of Santorini** consists of a number of thin scattered bundles of fibres from the fascia over the parotid gland and the angle of the jaw, which reach the skin at the angle of the mouth. It is a detached upper portion of the platysma myoides. By its action it draws the angle of the mouth outwards and even a little downwards; hence it does not come into play in laughter, as its name would imply, but rather in grinning.

The **depressor anguli oris** (*triangularis menti*) arises from the lower border of the inferior maxilla, between the mental foramen and the attachment of the masseter. Narrowing, it passes to the angle of the mouth, its fibres being partly attached to the skin, and partly continued into the upper part of the orbicularis.

The **depressor labii inferioris** (*quadratus menti*) arises from the lower jaw, along a line passing from below the mental foramen nearly to the symphysis. Its fibres, passing among those of the orbicularis, are inserted into the skin of the lower lip. A quantity of fatty tissue is interspersed among the fibres of the muscle.

The **levator menti** (*musculus superbus*) springing compactly from the incisor fossa of the lower jaw, spreads downwards and forwards to be inserted into the skin of the chin, its inner fibres, decussating with those of its fellow of the opposite side.

The **buccinator** arises behind from the pterygo-maxillary ligament, and by its margins from the alveolar ridges of the maxillary bones opposite the molar teeth. Becoming narrower and thicker as it passes forwards, it reaches the angle of the mouth and is continued into the orbicularis of both lips, the central fibres decussating with one another, the marginal ones being continued onwards without decussation. It is pierced opposite the second molar tooth of the upper jaw by the duct of the parotid gland (Stenson's duct).

The **musculi incisivi**, superior and inferior, are deep accessory slips of the orbicularis oris. The superior arises from the incisor fossa of the superior maxilla, and from the nasal septum (naso-labialis), and passes outwards to the angle of the mouth among the fibres of the orbicularis. The inferior, arising from the incisor fossa of the lower jaw, likewise passes outwards to the angle.

The **orbicularis oris** appears as an elliptical muscle of a breadth nearly uniform all round, and corresponding to the depth of the free lip in the middle line. It is closely connected with the skin on the surface, and especially at the margin of the lips, but is separated from the mucous

membrane by the labial glands and the coronary arterial arches. The more superficial fibres are derived from the elevators and depressors of the angles of the mouth. Deeper than those are found the fibres of the buccinator muscles, and deepest of all lie those of the musculi incisivi. The bundle of fibres running in the margin of the lips is somewhat distinct from the rest of the muscle, and is derived from the buccinators. The fibres of the elevators and depressors of the lips pass obliquely amongst the transverse fibres to reach the skin, and, in addition to these, a special set of oblique fibres has been described as being peculiarly well developed in the child, passing between the mucous membrane and the skin near the margin of the lips. At the angle of the mouth the fibres of the zygomaticus major, the risorius, and the upper part of the platysma are partially blended with the orbicularis.

The movements of the lips depend on the combined and antagonistic actions of the muscles which pass to the orbicularis. The aperture of the open mouth is widened by the action of the buccinators in combination with the elevator and depressor muscles of the lips. By the combined actions of the elevators and depressors of the angles of the mouth the oral aperture is narrowed. The buccinators draw outwards the angles and press the lips against the teeth, and in this way play an important part in the process of mastication. When the aperture of the lips is narrowed by the other muscles, the graduated contraction of the buccinators governs the expulsion of air from the buccal cavity.

THE MUSCLES AND FASCIA OF THE ORBIT.

The cavity of the orbit contains the globe of the eye, which is placed in the fore part, and, in addition, six muscles which act upon the eyeball. Another muscle, the elevator of the upper lid, is also, in its greater part, contained within the orbit. The rest of the cavity is filled, even in the most emaciated subjects, with soft fat, which, along with the fascia which divides it into lobes, and sheaths the muscles and surrounds the posterior part of the globe, plays an important part in maintaining the position of the eyeball and in modifying the actions of the muscles upon it. The muscles which act upon the eyeball are the four straight and the two oblique muscles.

The **four recti or straight muscles**—the superior, inferior, external, and internal—take origin at the back of the orbit from a common tendon, somewhat aponeurotic in its nature, which is partially divided into two portions, an upper and lower. The common tendon is attached to the upper, inner, and lower margins of the optic foramen, thence it crosses the sphenoidal fissure to a prominent point on the posterior margin of the orbital surface of the great wing of the sphenoid bone; a tendinous band connected with the origin of the external rectus muscle crosses the fissure somewhat higher up, and connects the outer ends of the upper and lower

portions of the tendon. The recti muscles are inserted tendinously into the anterior part of the sclerotic coat of the eyeball, at distances varying from a third to a fourth of an inch from the margin of the cornea or transparent portion of the wall of the globe. The direction of the muscles as they pass forwards is of importance in connection with their actions. The superior and inferior muscles pass outwards as well as forwards, the external rectus markedly outwards, the internal almost directly forwards. The external rectus rises partly from the upper and partly from the lower portion of the common tendon; between its heads the upper and lower divisions of the third, the ophthalmic division of the fifth, and the sixth nerves enter the orbit, and the ophthalmic vein emerges.

The **oblique muscles** are two in number, the superior and inferior. The superior arises in close proximity to the upper and internal recti immediately in front of the optic foramen, and is continued forwards close to the inner angle of the orbital roof as far as a cartilaginous pulley, which is attached to a depression on the orbital surface of the frontal bone, close to the margin of the cavity. The rounded tendon of the muscle, lubricated by a synovial sheath, turns over the pulley, and is continued backwards, outwards, and downwards, passing underneath the tendon of the superior rectus, by the outer margin of which it is inserted into the sclerotic, a little behind the middle of the globe. The inferior or smaller oblique arises from the floor of the fore part of the orbit, from a depression in close proximity to the margin of the bony canal which gives passage to the nasal duct. It passes outwards and backwards underneath the inferior rectus, and turns upwards to be inserted under cover of the external rectus into the posterior part of the globe, in line with the attachment of the superior oblique.

The **levator palpebrae superioris** arises by a narrow pointed tendon from the small wing of the sphenoid bone, immediately above the optic foramen. Broadening as it passes forwards, the muscle lies immediately above the superior rectus. Close behind the anterior margin of the orbit, it ends in a fibrous expansion, which is inserted into the tarsal membrane of the upper lid, and into the outer and inner tarsal ligaments. A few fibres are detached to the conjunctiva, and a few are given to the pulley of the superior oblique muscle.

The external rectus is supplied by the sixth nerve, the superior oblique by the fourth, all the others by the third nerve.

The **fascia of the orbit** presents a somewhat complicated arrangement; to special portions of it the names external capsule and internal capsule have been given.

The *external capsule* forms sheaths for the four straight muscles, and gives offsets which inclose the levator palpebrae and superior oblique. It is weak in the posterior part of the orbit, but stronger in front. Traced forwards from the optic foramen upon the straight muscles, it is found as a thin layer stretching between the margins, and splitting to inclose

each muscle. The muscles are ensheathed, however, only for about four-fifths of their length, for before reaching the tendons of insertion the external capsule splits into two portions. The posterior portion, continuous with the layer on the surfaces of the muscles directed towards the optic nerve, is reflected backwards behind the eyeball, embraces the optic nerve, and is continued backwards on it posteriorly as an outer sheath. The anterior portion sweeping off the orbital surfaces of the muscles is continued forwards to the margins of the orbit, where it is partly attached to the bone and partly continued into the tissue of the eyelids. This layer of fascia as it passes forwards forms sheaths for portions of the inferior and superior oblique muscles. Four specially strengthened bands are described as connected with it, passing forwards to the bony margin of the orbit, one from each of the sheaths of the recti muscles. The external band is the strongest; it stretches from the sheath of the external

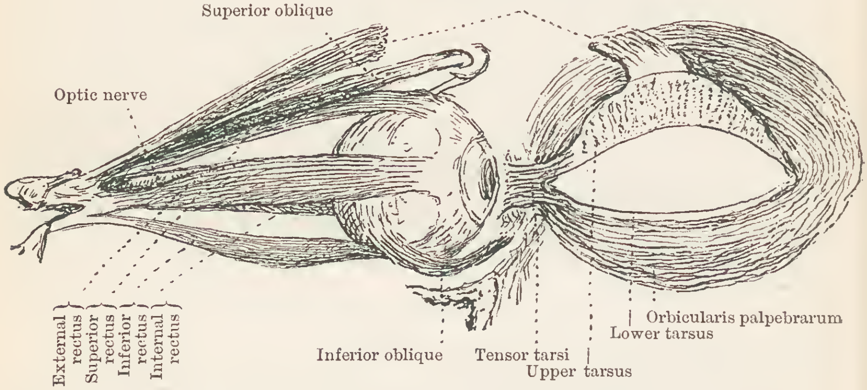


FIG. 272.—ORBITAL MUSCLES OF THE RIGHT SIDE. The eyelids have been turned over to the inner side, and are viewed from their deep surface.

rectus to the orbital process of the malar bone, where it is connected with the outer tarsal ligament. The band from the internal rectus is connected with the lachrymal crest. The superior and inferior bands are not so well marked as the other two.

The *internal capsule*, the *capsule of Tenon*, is a very delicate layer which covers the posterior part of the globe, and is continued back as an inner sheath to the optic nerve. It passes forwards on the globe nearly to the cornea, and in front is attached to the ocular conjunctiva. It likewise sends a delicate reflexion for a short distance upon each of the tendons inserted into the globe. Between the internal capsule and the sclerotic lies a narrow space, which is traversed by delicate trabeculae of connective tissue, and by vessels and nerves; it is regarded as a lymph space, and it acts to a certain extent as a synovial socket, within which the eyeball glides. In extirpating the eye the surgeon, in separating its attachments, seeks to avoid injuring the capsule. The

space extends for a short distance upon the orbital or free surface of each of the tendons, but does not pass round to the ocular surface or surface of pressure, the capsule being closely adherent to the margins of the tendons.

Actions of the muscles of the orbit. The eyeball does not appreciably change its form nor its position as a whole under the actions of the muscles; the motions imparted to it are those of rotation round a point placed immediately behind the centre of its antero-posterior axis. The maintenance of position probably depends partly on the antagonistic actions of the straight and oblique muscles, and partly on the support afforded by the orbital fascia, and the influence which it exercises in modifying the actions of the muscles. The four straight muscles are intimately connected with the fascia, more especially with the bands which pass to be attached to the orbital margins, and it is probable that these bands, by their gradual extension during muscular action, act as agents, moderating to a certain extent the direction in which the force is applied to the globe, and finally, by their complete tension, play the part of tendons of arrest. When the eyeball is in the position from which its movements are calculated, the pupil being directed forwards, its antero-posterior axis is parallel to the antero-posterior axis of the body. The axis of the orbit, however, is directed outwards as well as forwards; this fact requires to be borne in mind in the study of the actions of the individual muscles. There are three primary axes round which a globular body may rotate, but the movements of the eye are limited, and they are most conveniently described in terms which refer to the manner in which they affect the position of the cornea. Rotation of the eyeball round its vertical axis turns the cornea outwards or inwards according to the direction in which it takes place; the movements are spoken of as abduction and adduction of the cornea. In a similar manner rotation round the transverse axis results in elevation or depression of the cornea. Rotation round the antero-posterior axis would produce a rotation of the cornea. A simple movement of rotation of the cornea does not occur in the case of the eye, but a very slight inclination of the vertical meridian of the globe takes place in the oblique movements of the cornea, in which vertical and transverse displacement are combined. Movements of elevation or depression of the cornea take place in the two eyes simultaneously; when the gaze is fixed on a near object both eyes are turned inwards; when the gaze is directed laterally there is abduction in one case and adduction in the other. Movements in which the cornea is turned outwards or inwards are effected by the external and internal recti muscles. Upward movement of the cornea is caused principally by the superior rectus, but as the muscle passes somewhat outwards to its insertion, in the line of the orbital axis, a certain amount of oblique rotation is communicated to the ball by its contraction. The inferior oblique muscle, acting in concert with the superior rectus, corrects

the obliquity of the movement, with the result that by the simultaneous actions of the two muscles a direct upward movement of the cornea takes place. The levator palpebrae is closely associated by direct connection through the fascia, and in its nerve supply, with the superior rectus, and the upper eyelid is raised as the pupil is turned upwards. The inferior rectus, like the superior, is directed somewhat outwards, and the obliquity of its action is corrected by the superior oblique muscle. Pulled on in the dead subject the oblique muscles would produce an oblique movement of rotation of the eyeball, the superior depressing and abducting the cornea, the inferior elevating and abducting. By the combination of different muscles various degrees of oblique movement of the cornea may be produced. The amount of upward movement which actually takes place has been calculated as about 34 degrees, downward 57 degrees, outward 42 degrees, inward 45 degrees.

SUPRA-HYOID MUSCLES.

Three subsidiary groups of muscles are treated together under this heading—(*a*) a set connecting the hyoid bone with the lower jaw and with the styloid and mastoid processes; (*b*) a set passing from the hyoid bone and styloid process to the tongue, the extrinsic muscles of the tongue; (*c*) a muscle from the styloid process to the pharynx and larynx. They present relations to the vessels and nerves of the upper part of the neck, which can be conveniently studied together.

The **digastric** muscle is formed of two fleshy bellies and an intervening tendon. The posterior belly, longer than the anterior, arises from the digastric fossa of the mastoid process, and is directed forwards and downwards to the tendon. The anterior belly, broader than the posterior, springs from an oval area on the lower margin of the inferior maxilla, close to the symphysis, and is directed downwards and slightly backwards. The intervening tendon, nearly two inches in length, is placed immediately above the hyoid bone, to which, at the junction of the body with the great cornu, it is bound by aponeurotic fibres. At its origin from the digastric fossa the muscle is deeply placed under the other muscles connected with the mastoid process; the intervening tendon is crossed by a portion of the fibres of the stylo-hyoid muscle; in the rest of its area the muscle is superficial. Absence of one or other of the bellies has been noted; the anterior belly is occasionally double, and in rare cases the posterior belly is double.

The **mylo-hyoid**, a thin, four-sided muscle, rises from the mylo-hyoid ridge of the lower jaw. The more posterior fibres are inserted into the anterior surface of the body of the hyoid bone, the more anterior into a median fibrous raphe, which extends from the hyoid bone to the symphysis. The most anterior fibres are very short. The anterior belly of the digastric partly covers the under or superficial surface of the muscle.

The muscles of opposite sides together form a muscular floor for the buccal cavity.

The **genio-hyoid** springs from the lower genial tubercle of the inferior maxilla, and is inserted into the anterior surface of the body of the hyoid bone. It is a small rounded bundle, and lies on the upper or deep surface of the mylo-hyoid, close to the middle line.

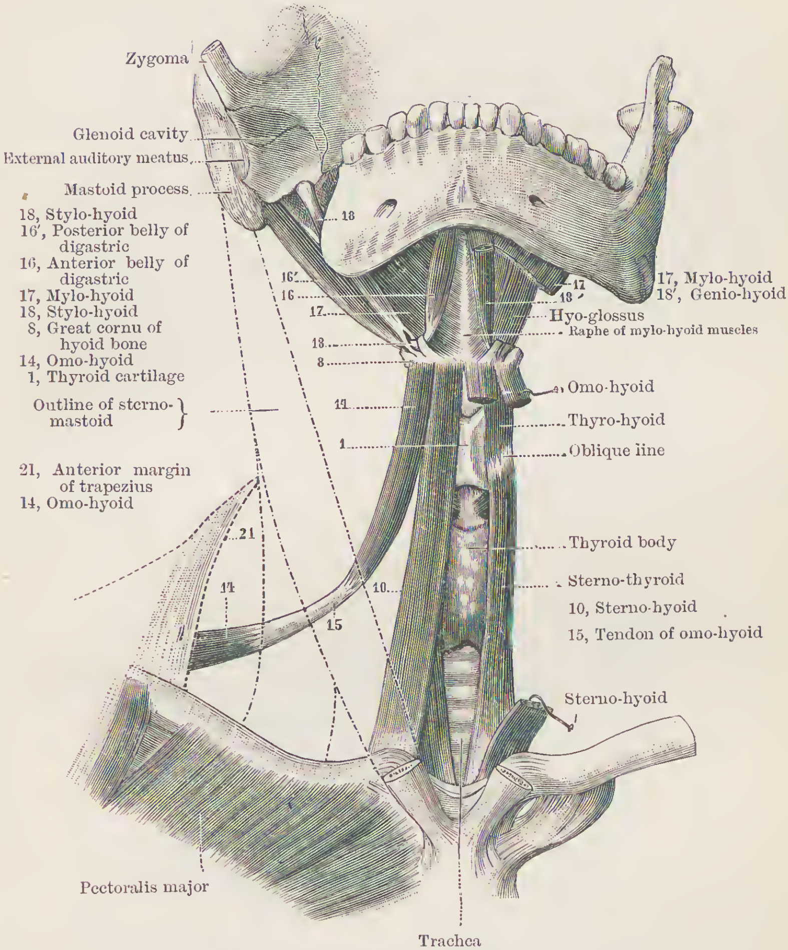


Fig. 273.—The Muscles connected with the Hyoid Bone. (L. Testut.)

The **stylo-hyoid,** a slender band, springs by a short tendon from the posterior and external part of the base of the styloid process. It passes downwards and forwards and is inserted into the anterior surface of the lateral part of the body of the hyoid bone. It is at first deeply placed, but afterwards becomes superficial, as it lies above the upper border of the posterior belly of the digastric, and its fibres passing to insertion embrace the intervening tendon of that muscle. The *stylo-hyoideus alter*

is the name given to an occasional muscle passing from the styloid process either to the great or small cornu of the hyoid bone.

Nerves. The stylo-hyoid and the posterior belly of the digastric are supplied by the seventh nerve, the mylo-hyoid and the anterior belly of the digastric by a branch from the inferior maxillary division of the fifth. The genio-hyoid receives its supply from the twelfth or hypoglossal nerve.

Actions. The muscles act both on the hyoid bone and the lower jaw. When the jaw is fixed the hyoid bone, and with it the larynx, is drawn upwards by the digastric, upwards and forwards by the mylo-hyoid and genio-hyoid, and upwards and backwards by the stylo-hyoid. The hyoid bone is drawn upwards in the action of swallowing. The mylo-hyoid in contracting raises the floor of the mouth and pushes the tongue upwards. The digastric depresses the lower jaw and opens the mouth.

The **stylo-glossus**, a narrow band, springs from the styloid process near its extremity, and from the stylo-hyoid ligament. It passes forwards and downwards, and is applied to the lower surface of the tongue at its border, its fibres becoming blended with those of the hyo-glossus and of the intrinsic muscles.

The **hyo-glossus**, thin and four-sided, springs from the upper border of the lateral part of the body, and from the great cornu of the hyoid bone. It passes upwards to the under surface of the posterior part of the tongue at its border, where its fibres, along with those of the

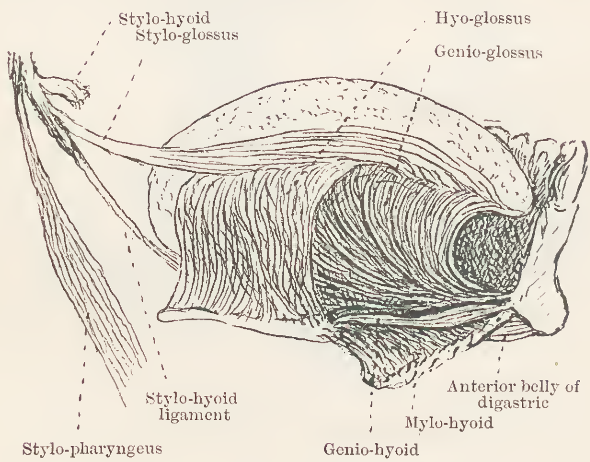


FIG. 274.—THE EXTRINSIC MUSCLES OF THE TONGUE.

stylo-glossus, to the inner side of which they are at first placed, become interlaced with those of the intrinsic muscles. A small muscular slip (*chondro-glossus*) occasionally arises from the smaller cornu, and passes on the surface of the hyo-glossus to the tongue. An accessory slip sometimes springs from the thyro-hyoid ligament.

The **genio-glossus,** fan-shaped, springs from the upper genial tubercle of the inferior maxilla; the fibres pass into almost the whole length of the under surface of the tongue from near the tip backwards into the glosso-epiglottic fraenum, and into the body of the hyoid bone. It lies close to the middle line, and its inner surface is in contact with that of its fellow of the opposite side; the genio-hyoid lies along its lower border, and the hyo-glossus and stylo-glossus are in contact with its outer surface.

Nerves. The stylo-glossus, hyo-glossus, and genio-glossus are supplied by the hypoglossal nerve.

Actions. The stylo-glossus draws the tongue backwards and upwards, the hyo-glossus backwards and downwards. The genio-glossus depresses the tongue, and its anterior fibres retract, while its posterior fibres protrude the organ. The genio-glossus and stylo-glossus muscles of the two sides acting together and along with the palato-glossi turn up the edges and depress the centre of the tongue, and the hyo-glossus muscles oppose this action.

The **stylo-pharyngeus** springs by a short tendon from the inner part of the base of the styloid process. Passing downwards and inwards, it becomes flattened and enters the wall of the pharynx, passing between the superior and middle constrictors. It is inserted with the palato-pharyngeus muscle chiefly into the upper and posterior edges of the thyroid cartilage, and partly into the wall of the pharynx and the side of the epiglottis. It is supplied by the glosso-pharyngeal nerve, and acts as an elevator of the pharynx and larynx.

Relations of the supra-hyoid group of muscles. This group of muscles presents important relations to the large vessels and nerves of the upper part of the neck. The external and internal carotid arteries pass upwards to the head from the point of division of the common carotid opposite the upper border of the thyroid cartilage. The external, the more superficial, reaches to a spot behind the neck of the lower jaw, crossing in its course over the styloid process; the internal passes on the deep surface of the process to the carotid foramen. Along with the internal carotid artery are closely associated the internal jugular vein and the vagus or pneumogastric nerve. The stylo-hyoid muscle, springing from the base of the process, crosses along with the posterior belly of the digastric superficially to the external carotid artery; and the stylo-pharyngeus, also from the base of the process, passes between the external and internal vessels; the stylo-glossus, from the tip of the process, does not come into actual relation with either vessel. The internal carotid artery, with its accompanying structures, passes upwards in close contact with the wall of the pharynx. Three nerves pass downwards and inwards to the tongue; they are the hypoglossal, the glosso-pharyngeal, and the lingual branch of the fifth. The hypoglossal nerve crosses superficially to the external carotid artery, and in its curved course passes slightly further down in the neck than the lower margins of the stylo-hyoid and the posterior belly of the

digastric muscles. The glosso-pharyngeal nerve, lying along the lower border of the stylo-pharyngeus muscle, lies between the external and internal arteries. The lingual nerve is placed further forwards on the deep surface of the ramus; it does not come into relation with either vessel, but crosses the stylo-glossus muscle. Further forwards, in the region underneath the body of the lower jaw, the submaxillary salivary gland lies on the surface of the mylo-hyoid muscle in the *submaxillary triangle*, the region marked off by the anterior belly of the digastric, the stylo-hyoid, and the border of the inferior maxilla; its duct turns round the posterior border of the mylo-hyoid and passes across the muscles of the tongue to reach the floor of the mouth. Besides the duct and the three nerves already mentioned, the lingual artery and veins cross the sublingual muscles. On the deep surface of the mylo-hyoid and upon the hyo-glossus lie, in order from below upwards, the ranine vein, the hypoglossal nerve, the duct of the gland (Wharton's duct), and the lingual nerve; on the deep surface of the hyo-glossus and upon the genio-glossus lie, in the same order, the lingual artery and its venae comites and the glosso-pharyngeal nerve. The sublingual salivary gland lies upon the anterior part of the genio-glossus, under cover of the mucous membrane of the mouth, and rests below on the mylo-hyoid.

MUSCLES ATTACHED TO THE RAMUS OF THE JAW.

Four muscles are on each side attached to the ramus of the jaw or its processes, and play an important part in the process of mastication, in which they are assisted by the muscles of the tongue, lips, and cheeks.

The **masseter**, strong and four-sided, springs from the zygomatic arch, and is inserted into the outer surface of the ramus and coronoid process of the lower jaw. It is formed of three sets of fibres, differing from one another in direction. The largest and most superficial portion passes downwards and backwards. It springs from the lower border of the anterior two-thirds of the arch by a strong tendon which sends septa among the muscular fibres; it is inserted into the lower half of the ramus. The second portion, the fibres of which pass directly downwards, springs from the inner surface of the anterior two-thirds and the lower border of the posterior third of the arch, and is inserted into the upper portion of the ramus; except at its posterior and upper angle, it is overlapped by the first part. The third portion, the fibres of which are directed downwards and forwards, springs from the inner surface of the posterior third of the arch, and is inserted into the outer surface of the coronoid process; it is completely overlapped by the second part. The third portion is easily separable from the second, but has usually been described along with it.

The **temporal** muscle, flat and fan-shaped, springs from the whole surface of the temporal fossa, with the exception of the portion formed by the malar bone, and from the overlying temporal fascia, except at its lower part. The muscular fibres converge, the anterior descending almost

vertically, the posterior passing forwards almost horizontally. It is inserted by tendon into the upper and anterior borders of the coronoid process, and partly by tendon and partly by fleshy fibres into the whole inner surface of the process and into the anterior area of the inner surface of the ramus.

The **external pterygoid** muscle arises from the walls of the zygomatic fossa by two fleshy heads—the upper from the zygomatic surface of the great wing of the sphenoid, the lower and larger from the outer surface of the external pterygoid plate. The fibres, converging, pass backwards and a little outwards, and are inserted partly into the depression on the front of the head of the lower maxilla, and partly into the inter-articular fibro-plate of the temporo-maxillary articulation.

Fig. 275.—The Temporal Muscle. The fibres at *a* are reflected forwards; they arise from the temporal fascia, and are inserted into the anterior border of the coronoid process: *b*, the temporo-maxillary articulation represented as when the mouth is shut.

Fig. 276.—The Pterygoid Muscles, from the outer side after removal of part of the lower jaw. *a*, External pterygoid; *b*, internal pterygoid; *c*, buccinator; *d*, temporo-maxillary articulation represented as when the mouth is open.

The **internal pterygoid** muscle arises in the pterygoid fossa from the inner surface of the external pterygoid plate, partly by fleshy fibres, and partly by a flattened tendon which is continued within the substance of the muscle. Additional fibres take origin, external to the lower fibres of the external pterygoid, from the outer surface of the tuberosity of the palate, and the neighbouring area of the superior maxilla. It is directed downwards, backwards, and outwards, and is inserted into a rough impression on the inner surface of the ramus of the jaw at the angle.

Relations. The masseter is entirely superficial, and the temporal almost entirely so. The other two are deeply placed in the zygomatic fossa. The heads of the external pterygoid are placed one on each side of the pterygo-maxillary fissure, and the muscle, in reaching to its insertion, passes between the internal lateral ligament of the articulation (spheno-maxillary ligament) and the inner surface of the lower maxilla. The internal pterygoid arises, for the greater part, on the deep surface of the external pterygoid, and has the tensor palati on its internal aspect.

The parotid gland, which lies behind the ramus, sends its duct forwards across the masseter, and a small accessory portion of the gland usually lies beside the duct on the surface of the muscle. A deep prolongation of the gland passes on the deep surface of the ramus into contact with the internal and external pterygoid muscles. The facial nerve and the external carotid artery lie in the substance of the gland; the nerve sends branches forwards over the masseter, and the internal maxillary branch of the artery runs forwards on the deep surface of the ramus and usually crosses the outer surface of the external pterygoid to enter, between its heads, the pterygo-maxillary fissure. The inferior maxillary division of the fifth nerve, which escapes from the skull by the foramen ovale, breaks up into its branches on the deep surface of the external pterygoid; of these the

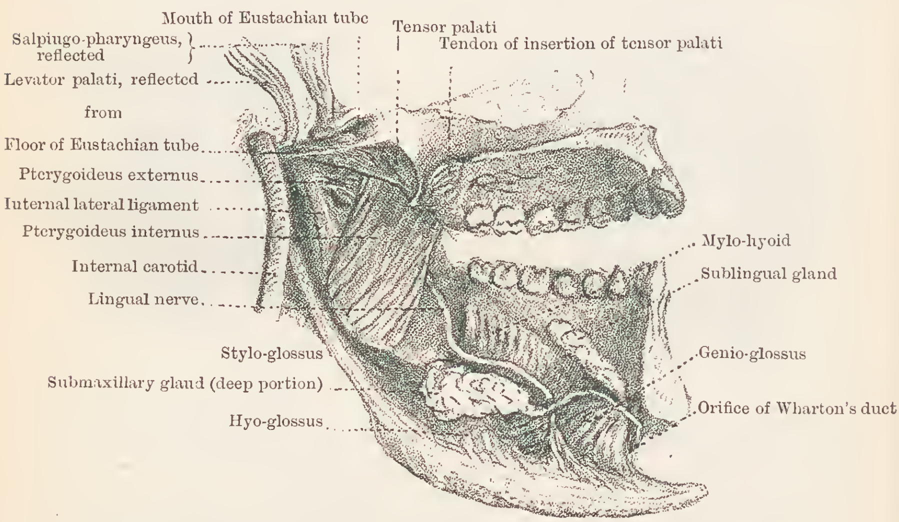


FIG. 277.—PTERYGOID AND OTHER MUSCLES, displayed by reflecting the tongue downwards.

deep temporal and masseteric pass over the upper border of the muscle, the buccal emerges between its heads, and the lingual and dental descend beneath its lower border.

Nerves. All the muscles of the group are supplied by the inferior maxillary division of the fifth nerve.

Actions. The masseter, temporal, and internal pterygoid muscles of opposite sides usually act together and draw the lower jaw upwards against the upper maxilla. The external pterygoid draws the head of the jaw forwards, and thus comes into play along with other muscles in opening the mouth. Its chief use is in grinding the food between the teeth, the muscles of opposite sides acting alternately. The posterior fibres of the temporals are opponents of the external pterygoids.

The **temporal fascia**, a strong, firm layer, is attached to the posterior margin of the malar bone, the temporal ridge of the frontal and parietal

bones, the supra-mastoid ridge of the temporal bone, and the zygomatic arch. It is a single sheet above, but splits into two about two inches from its lower margin, and a little fat lies between the layers as they descend to the outer and inner surfaces of the zygoma. On the deep surface of the lower part of the fascia a quantity of soft fatty tissue lies between it and the temporal muscle.

The **masseteric fascia** is a moderately strong layer which covers the masseter muscle, and is continued forwards from the fascia of the parotid gland. Anteriorly it passes into a more delicate layer which overlies the buccinator. On the surface of the buccinator a quantity of soft fatty tissue, "the buccal pad," peculiarly well developed in children, lies underneath the fascia, and is continuous on the deep surface of the ramus with the fat under the temporal fascia.

MUSCLES OF THE PHARYNX.

General description and relations. The pharynx, the dilated upper extremity of the digestive tube, is open in front to the nose, mouth, and larynx, and is attached to the base of the skull above. At the sides and behind, its walls are formed by aponeurotic tissue, covered internally by a mucous membrane and externally by a layer of muscles, the chief of which are the three constrictors, superior, middle, and inferior. Each is formed of lateral portions, which meet in the middle line behind in a central raphe continued down from the basilar process. They partially overlap one another from below upwards. The lower margin of the inferior constrictor embraces the oesophagus; its upper margin slopes upwards and backwards on the surface of the middle constrictor to reach the middle line above the level of the hyoid bone. The lower fibres of the middle constrictor descend under cover of the inferior muscle for some distance; its upper fibres ascending as far as the base of the skull cover in turn a portion of the superior muscle. The fibres of the superior constrictor are chiefly horizontal in direction; it reaches to the base of the skull in the middle line only, and in the interval between its upper margin and the skull the pharyngeal aponeurosis is stronger than elsewhere. The Eustachian tube and the levator palati pass over the upper border of the superior constrictor to enter the pharynx, the stylo-pharyngeus passes between the superior and middle constrictors, and the inferior laryngeal nerve ascends below the lower border of the inferior constrictor. The back of the pharynx lies upon the vertebral bodies and prevertebral muscles; the great vessels and nerves of the upper part of the neck lie by its sides. Supernumerary muscular slips passing to the wall of the pharynx are frequently found; they may arise from the spine of the sphenoid, the internal pterygoid plate, the under surface of the petrous bone, the basilar process, or the mastoid process.

The **inferior constrictor** arises from the side of the cricoid cartilage, and from the ala and upper border of the thyroid cartilage in the region

behind the oblique line. On their way to the central raphe the lower fibres are almost horizontal, while the more superior ascend with increasing degrees of obliquity.

The **middle constrictor** arises from the upper border of the great cornu of the hyoid bone and the extremity of the stylo-hyoid ligament. The middle fibres are horizontal; the superior ascend, and the inferior descend, with considerable obliquity.

The **superior constrictor** arises by slips attached in series from below upwards to the side of the tongue and mucous membrane of the mouth, the extremity of the mylo-hyoid ridge of the inferior maxilla, the pterygo-

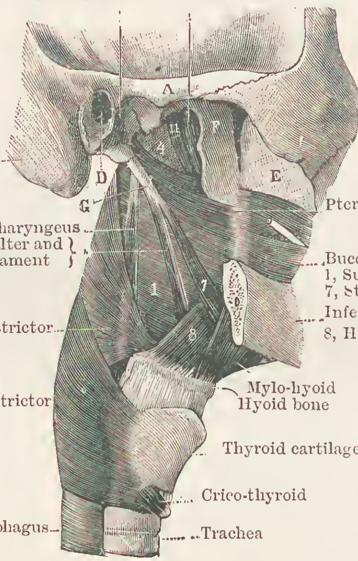


FIG. 278.—THE WALL OF THE PHARYNX. (L. Testut.)

maxillary ligament, and the lower part of the posterior border of the internal pterygoid plate. The fibres are mostly horizontal, but the upper and lower slightly diverge. The tonsil lies on its inner surface. It is united to the buccinator by the pterygo-maxillary ligament.

Nerves. The constrictors are supplied through the pharyngeal plexus, probably from the bulbar portion of the spinal accessory nerve; the inferior constrictor, in addition, receives branches from the superior and inferior laryngeal nerves.

Actions. The muscles contract from above downwards. In deglutition the lower part of the pharynx is raised; the superior constrictor and the upper part of the middle constrictor assist in shutting off the nasal passages; the lower part of the middle constrictor and the inferior constrictor narrow the lateral diameter of the pharynx.

THE MUSCLES OF THE SOFT PALATE.

The soft palate or velum, attached in front to the posterior margin of the hard palate, is a movable curtain, with a free pendulous posterior border projecting into the pharynx and prolonged in the middle line into a small process, the uvula. It is formed by a somewhat ill-defined

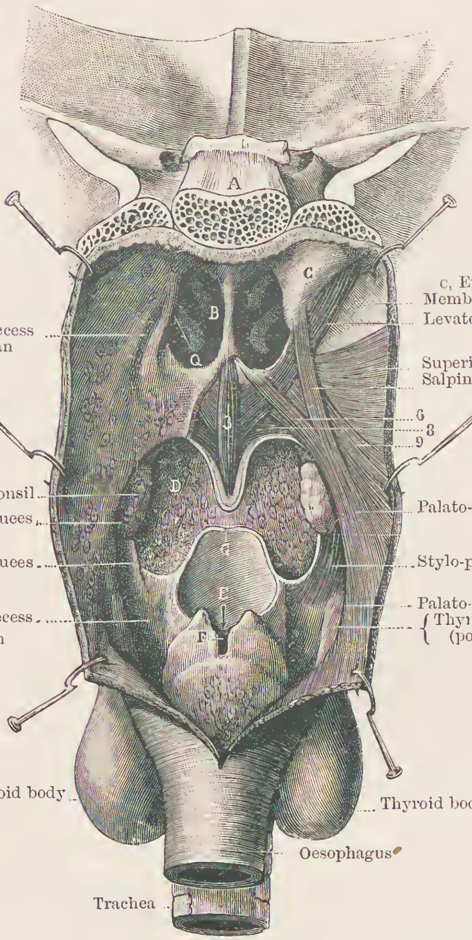


FIG. 279.—MUSCLES OF THE SOFT PALATE AND PHARYNX, from behind. (L. Testut.)

fibrous layer, which gives origin and attachment to various muscles, and is covered by mucous membrane, continuous on the upper surface with that of the nasal cavities, on the under with that of the mouth. At its lateral margins it is attached to the internal pterygoid plates and to the wall of the pharynx by the muscles which enter and pass from it. Its muscles reach it from above, pass from it downwards, or are confined entirely within its substance. To the last group belong the elevators of the uvula, one on each side of the middle line, passing backwards along the

upper surface to reach the uvula, where they become blended. The muscles which pass downwards from it are on each side, the palato-glossus and palato-pharyngeus forming respectively the anterior and posterior pillars of the fauces between which lies the tonsil. The muscles which reach it from above are likewise two on each side, the tensor palati and levator palati, the former, anterior in position, springing from the sphenoid, the latter from the petrous bone. In the soft palate the muscular fibres of the levator uvulae lie above those of the levator palati, and both are embraced above and below by those of the palato-pharyngeus, while the palato-glossus forms the lowest stratum. The tendinous fibres of the tensor palati enter the aponeurosis of the palate beneath the insertion of the levator palati.

The **levator uvulae** (*azygos uvulae*) arises from the posterior nasal spine and the aponeurosis of the soft palate. In the uvula it blends with its fellow of the opposite side, and is inserted into the sub-mucous tissue.

The **palato-glossus** arises on the under surface of the palatal aponeurosis, its fibres decussating across the middle line with those of the muscle of the opposite side. It descends in the anterior pillar of the fauces to the side of the posterior part of the tongue, where it becomes blended with the transverse lingual fibres. At its posterior border a few fibres spread over the surface of the tonsil (amygdalo-glossus).

The **palato-pharyngeus** arises in two layers, the smaller from the upper surface of the soft palate above the levator uvulae, the fibres decussating across the middle line with those of the opposite side, the lower from the margin of the hard palate and from the palatal aponeurosis. A small slip (*salpingo-pharyngeus*) descends to it from the lower margin of the cartilage of the Eustachian tube. The muscle passes backwards and downwards in the posterior pillar of the fauces to the wall of the pharynx, and, spreading, blends with the stylo-pharyngeus to be inserted partly into the upper and posterior borders of the thyroid cartilage, and partly into the wall of the lower part of the pharynx, where some of its fibres reach the middle line.

The **tensor palati** (*circumflexus palati*) has a broad origin from the sphenoid bone behind and internal to the foramen ovale, stretching from the spine to the scaphoid fossa at the root of the internal pterygoid plate. It also receives fibres from the outer side of the cartilage of the Eustachian tube. The muscle forms a flattened band, which, descending, becomes tendinous, and turns round the hamular process, a small bursa intervening. The tendinous fibres spread out into the aponeurosis of the velum, and in addition are partly inserted into the transverse ridge of the under surface of the horizontal plate of the palate bone.

The **levator palati**, rounded in outline, springs by a narrow tendon from the under surface of the petrous bone in front of the carotid canal, and by some fibres from the lower edge of the hinder part of the cartilage of the Eustachian tube. The muscle passes downwards, forwards, and inwards,

over the border of the superior constrictor of the pharynx, and lies in close contact with the membranous portion of the wall of the Eustachian tube. It is inserted into the aponeurosis of the soft palate, many of its posterior fibres decussating with those of the opposite side.

Nerve supply. The nerve supply of the muscles of the soft palate is not yet, in all the cases, satisfactorily determined. The palato-glossus, palato-pharyngeus, and levator uvulae receive their nerves from the pharyngeal plexus, and it is probable, from the records of clinical experience and physiological experiment, that these branches reach the plexus from the bulbar portion of the spinal accessory nerve through the vagus and glosso-pharyngeal trunks. The levator palati is supposed, by many anatomists, to receive branches through Meckel's ganglion from the facial nerve, but it is more probable that its supply comes from the plexus in the way indicated above. The tensor palati receives a branch from the otic ganglion, presumably from the motor portion of the fifth, but it is possible that this twig may be derived from the glosso-pharyngeal nerve by way of the nerve of Jacobson, and the lesser superficial petrosal (W. A. Turner, *Journal of Anatomy and Physiology*, XXIII. 523).

Actions. The levator and tensor palati act together, raising and making tense the velum. The palato-glossus and palato-pharyngeus depress the soft palate on the one hand, or on the other raise the tongue and pharynx when the velum has been raised and made tense by its superior muscles. Along with a number of other muscles they all come into play in the act of swallowing. The food, after mastication, lies upon the surface of the tongue, which is then raised and drawn backwards by the action of the stylo-glossi muscles, together with the stylo-hyoidei and stylo-pharyngei, the mass being pressed against the under surface of the soft palate. The next stage, spasmodic in its nature, is characterized by the shutting off of the nasal, laryngeal, and anterior part of the buccal passages and the propulsion of the bolus into the grasp of the constrictors of the pharynx. The palato-glossi muscles contracting assist the tongue in shutting off the anterior part of the buccal cavity. The elevator muscles of the hyoid bone and larynx, the thyro-hyoid, genio-hyoid, mylo-hyoid, and stylo-hyoid, assisted by the palato-pharyngeus and stylo-pharyngeus, draw the larynx upwards under the tongue, which, by its pressure upon the epiglottis, completely closes the laryngeal orifice. The levator and tensor palati raise and make tense the palate. The stylo-pharyngei muscles contracting meet in the middle line and, assisted by the upper part of the superior and middle constrictors, prevent the food entering the nasal passages and, at the same time, draw upwards the lower part of the pharynx. The next stage of the process is involuntary, and consists in the contraction from above downwards of the constrictors of the lower part of the wall of the pharynx, by which the bolus is propelled onwards into the oesophagus. In vocalization the palate is raised and made tense by the levator and tensor muscles.

THE INFRA-HYOID GROUP.

This group comprises the sterno-hyoid, sterno-thyroid, thyro-hyoid, and omo-hyoid muscles.

The **sterno-hyoid** arises, along a narrow line, from the posterior surface of the inner extremity of the clavicle, the sterno-clavicular capsule, and, to a small extent, the manubrium sterni. It is inserted close to the middle line into the inner part of the lower border of the body of the hyoid bone. The muscle is ribbon-shaped, and varies in breadth from about one inch to one inch and a half.

The **sterno-thyroid** arises, close to the middle line, from the posterior surface of the manubrium, and from the cartilage of the first rib. It is inserted into the oblique line of the ala of the thyroid cartilage. It lies behind the sterno-hyoid, and is usually a little broader than that muscle.

The **thyro-hyoid** arises from the oblique line of the ala of the thyroid cartilage, and is inserted into the lower margin of the outer part of the body and the basal portion of the great cornu of the hyoid bone. It continues the line of the sterno-thyroid, and at its insertion is, to a great extent, covered by the omo-hyoid and sterno-hyoid muscles.

The **omo-hyoid** is formed of two ribbon-shaped bellies and an intervening tendon. The posterior belly rises from the upper margin of the scapula in the vicinity of the notch, and passes forwards and slightly upwards in the neck to the tendon, which lies beneath the sterno-mastoid muscle. The anterior belly ascends from the tendon with a slight inclination inwards to its insertion into the lower border of the outer part of the body of the hyoid bone.

Relations. The sterno-hyoid muscles of opposite sides converge as they ascend, the sterno-thyroids, close together below, diverge as they pass upwards. The muscles lie in front of the trachea and thyroid body, but a little above the sternum a narrow interval is left in the middle line, in which the windpipe is exposed, having, however, on its surface some fatty tissue, in which lie the inferior thyroid veins. At their origin the sterno-thyroid muscles lie in front of the innominate and left carotid arteries and the left innominate vein. The posterior belly of the omo-hyoid forms the upper boundary of a space, the other margins of which are formed by the clavicle and the sterno-mastoid, the *subclavian triangle*, in which the third part of the subclavian artery, surrounded by the cords of the brachial plexus, is sought for by the surgeon in the operation for ligature. A double layer of the deep cervical fascia binds down the posterior belly and intervening tendon of the muscle to the clavicle and the first rib and passes in front of the artery. The anterior belly of the omo-hyoid, in escaping from the cover of the sterno-mastoid at the level of the cricoid cartilage, crosses over the common carotid artery, and the angle between the two muscles is the spot where the ligature is usually applied to the vessel. Between the thyro-hyoid membrane and

the insertions of the muscles into the lower border of the hyoid bone a bursa usually intervenes. Variations among the infra-hyoid muscles are by no means infrequent. One or other of them, or one of the bellies of the omo-hyoid, is occasionally absent, and accessory bands are often present, more particularly in the case of the omo-hyoid.

Nerves. The thyro-hyoid receives a special branch from the hypoglossal. The others are supplied from the loop formed by the junction of a branch from the second and third spinal nerves with the descending branch of the hypoglossal. In all probability all the fibres of supply, even those from the hypoglossal, are derived from the first three spinal nerves through the connections which pass between the cervical plexus and the hypoglossal.

Actions. The sterno-hyoid and omo-hyoid depress the hyoid bone, the sterno-thyroid depresses the larnyx, while the thyro-hyoid either depresses the hyoid bone or elevates the larynx according to circumstances. The thyro-hyoid comes into play in raising the larynx in deglutition and in the production of the high notes of the voice; the others are called into action to depress the hyoid bone and larynx after deglutition, and in the production of the low notes.

THE LATERAL MUSCLES.

The **sterno-mastoid** (*sterno-cleido mastoid*) arises in two portions, sternal and clavicular, separated below by a narrow interval, and joining together in the lower third of the neck. The sternal portion springs by a short tendon from the anterior surface of the manubrium, the clavicular portion by mixed fleshy and tendinous fibres from the upper border of the inner third of the clavicle. The clavicular portion passes almost vertically upwards on the deep surface of the common mass, and, narrowing, is inserted by tendon into the tip of the mastoid process. The sternal portion, passing upwards and backwards on the surface of the muscle, and broadening, is inserted into the rough area on the outer surface of the process and into the outer third or half of the superior curved line of the occipital bone. Frequently a bundle of fibres (*cleido-occipitalis*) belonging to the clavicular portion passes upwards along the posterior border of the muscle to the superior curved line. Occasionally a muscular slip connects the anterior border of the trapezius with the posterior border of the sterno-mastoid.

The muscle is supplied by the spinal accessory nerve, and by branches from the second cervical nerve. It is inclosed in a strong sheath of the cervical fascia. The external jugular vein, descending, crosses it, and in the lower third of the neck lies along its posterior border; the anterior jugular vein passing outwards to join the external jugular crosses the deep surface immediately above the origin. The sterno-mastoid covers the lower portions of the sterno-hyoid and sterno-thyroid muscles, crosses the omo-hyoid, and at its insertion overlies the splenius, trachelo-

mastoid, and digastric muscles. The first and second parts of the subclavian artery lie behind it in the lower part of the neck. The common carotid artery is under its cover as far as the level of the cricoid cartilage of the larynx; above that level in the natural body with the fascia uncut the artery is overlapped by the anterior border of the muscle. The names *anterior* and

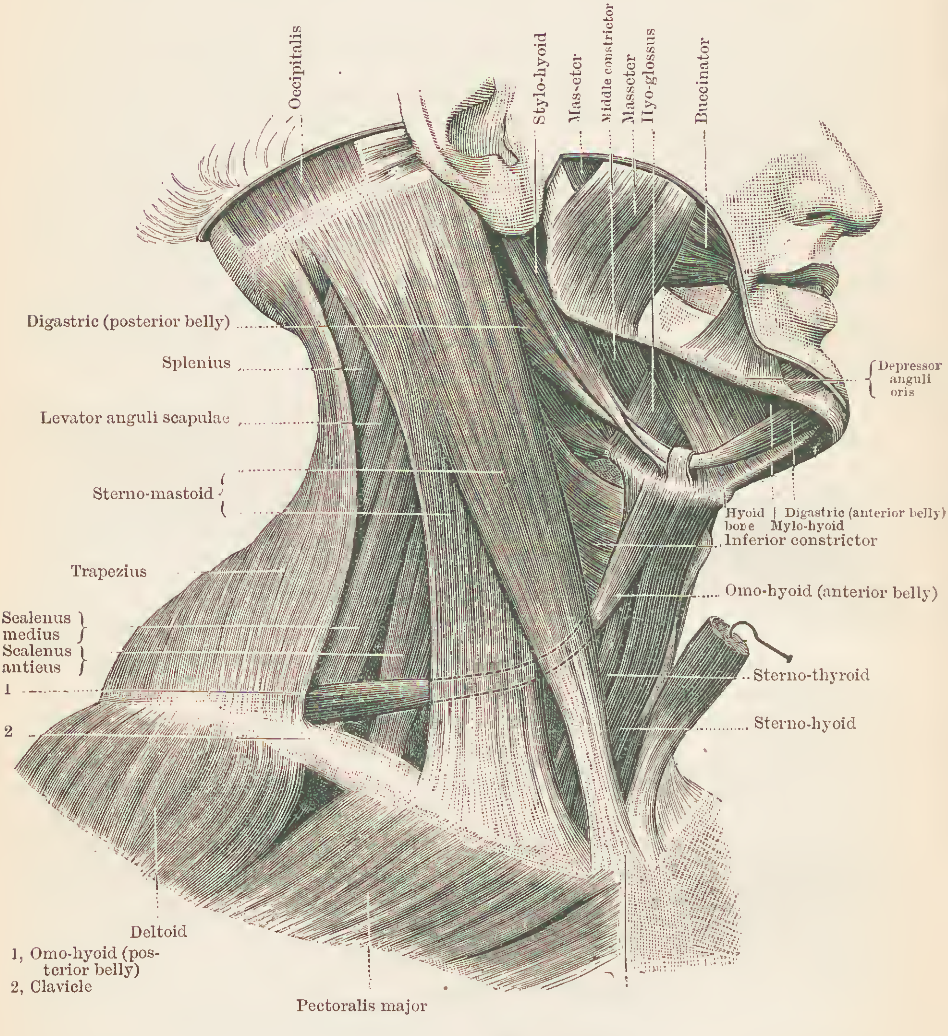


Fig. 280.—Lateral Muscles of the Neck. (L. Testut.)

posterior triangle are often used to designate the regions of the neck in front of and behind the muscle. Acting from the head the sterno-mastoid muscles raise the upper part of the chest wall, and come into play in forced inspiration. Acting from below the two muscles bend the neck and draw the head forwards; one acting alone produces an oblique movement of

rotation of the head, in which the ear is approached to the sternum and the face turned to the opposite side. In the operation for the relief of "wry-neck," the surgeon divides the muscle of the side from which the face is averted from a quarter to half an inch above its origin, taking care of the anterior and external jugular veins.

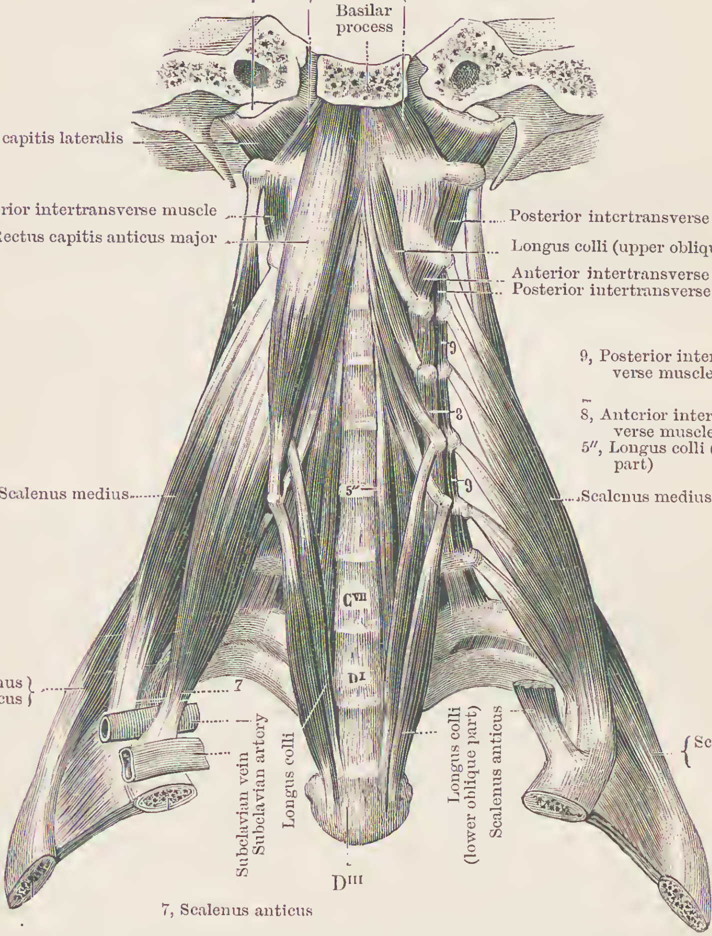


FIG. 281.—DEEP MUSCLES OF THE NECK. (L. Testut.)

The **scalenus anticus** arises from the anterior tubercles of the transverse processes of the cervical vertebrae from the third to the sixth. It is inserted into the scalene tubercle of the first rib in front of the groove for the subclavian artery.

The **scalenus medius** arises from the posterior tubercles of the transverse processes of the cervical vertebrae from the second to the sixth. It is inserted into the first rib behind the groove for the subclavian artery.

The **scalenus posticus**, smaller than the other two, is somewhat variable, being occasionally absent altogether. It arises from the posterior tubercles of a few of the lower cervical vertebrae, and is inserted into the upper border of the second rib, in close proximity to the place of insertion of the first slip of the serratus posticus superior muscle.

The scalene muscles all take origin by tendinous slips. The subclavian vein crosses the lower end of the anterior muscle, and the common carotid artery, with its accompanying structures, lying upon the transverse processes, is in front of the origins of the muscle; the phrenic nerve, descending, crosses the muscle from without inwards. The subclavian artery passes outwards over the first rib, between the attachments of the anterior and middle muscles, and the tubercle to which the former is attached is recognized by surgeons as the guide to the vessel in the operation for ligature. The nerves of the brachial plexus pass outwards between the two muscles, and lie in close proximity to the artery. Two of the branches of the plexus, the nerve to the rhomboids and the posterior thoracic, pass backwards through the middle scalene muscle. The scalene muscles elevate the upper ribs and come into play in forced inspiration; acting from below they produce flexion of the cervical portion of the column. They receive small branches from the anterior divisions of the cervical nerves as they emerge from the intervertebral foramina.

THE PREVERTEBRAL MUSCLES.

The **longus colli** muscle is divided into three portions, a vertical, and an upper and a lower oblique portion. The vertical portion springs by musculo-tendinous slips from the bodies of the three upper dorsal and two lower cervical vertebrae, and is inserted by similar slips into the bodies of the second, third, and fourth vertebrae of the neck. The lower oblique portion arises in common with the lower part of the vertical portion, and is inserted into the anterior tubercles of the transverse processes of the fifth and sixth cervical vertebrae. The upper oblique portion, larger than the lower, and sometimes separately described as the "atlantal" muscle, passes from the anterior tubercles of the transverse processes of the third, fourth, and fifth cervical vertebrae, and is inserted into the anterior surface of the atlas.

The **rectus capitis anticus major** arises by tendinous slips from the anterior tubercles of the transverse processes of the third and the succeeding cervical vertebrae. The slips unite to form a flattened fleshy band which is inserted into the basilar process of the occipital bone along an oblique line extending outwards and forwards from the pharyngeal spine for about half an inch.

The **rectus capitis anticus minor** arises from the anterior part of the base of the transverse process of the atlas, and is inserted into the basilar process of the occipital bone under cover of the outer margin of the larger rectus.

The **rectus capitis lateralis**, a small four-sided muscle, springs from the upper surface of the extremity of the transverse process of the atlas, and is inserted into the jugular process of the occipital bone.

The longus colli lies immediately on the vertebral bodies and the roots of the transverse processes; its upper part is covered by the rectus capitis anticus major. The rectus lateralis is in series with the posterior inter-transverse muscles of the neck, small rounded bundles which pass between the posterior tubercles of the transverse processes of the successive cervical vertebrae. Between the rectus lateralis and the posterior belly of the digastric the occipital artery passes backwards. The oesophagus, continued up into the pharynx, lies upon the muscles of this group, and by its sides the common carotid arteries, continued into the internal carotids, ascend in front of the transverse processes. The two smaller muscles are supplied by the first cervical nerve, the larger rectus by the first and second, and the longus colli by special twigs from the cervical nerve trunks. The longus colli flexes the cervical portion of the column, the rectus major and minor flex the head upon the column, the rectus lateralis produces a lateral movement of the head.

The **deep cervical fascia**, though nowhere very strong, is of importance surgically, and because in certain diseased conditions it is liable to undergo thickening and serves to determine the directions in which abscesses spread. It forms an exceedingly complicated structure, investing all the different muscles, the viscera and the larger bloodvessels and nerves of the neck.

Followed from the back of the neck, where it invests all the muscles, it may be traced from the border of the trapezius to the posterior edge of the sterno-mastoid, covering the splenius, levator anguli scapulae, and posterior belly of the omo-hyoid. Above, it is attached to the superior curved line of the occipital bone and to the mastoid process; below, where it is strongest, it is attached to the clavicle, and is pierced immediately behind the sterno-mastoid by the external jugular vein. Of its deeper septa in the posterior triangle the most important is a layer which invests and binds down the posterior belly of the omo-hyoid, retaining it in a much more horizontal position than the anterior belly; it is partly attached below to the first rib, and partly continued into the costo-coracoid membrane, and it covers and invests the scalenus anticus, at the outer border of which it has to be divided in the operation for ligature of the subclavian artery.

Traced forwards from the posterior triangle the fascia splits to inclose the sterno-mastoid, and the enveloping layers meet again at the anterior border of the muscle to be continued toward the middle line. Above, it is attached to the zygoma and to the lower jaw; below, it is attached to the clavicle and sternum. In the middle line above the level of the thyroid body it meets the layer of the opposite side as a single sheet, and is fixed to the hyoid bone. Below the level of the thyroid body,

the layers of fascia approaching one another from the opposite sides of the neck split into two just before reaching the middle line, and a double junction is effected, with the result that an interfascial space is formed in the front of the lower part of the neck, its walls being attached below to the anterior and posterior margins of the sternum. At its lower angles this space is prolonged for a short distance outwards on each side on the deep surface of the sternal head of the sterno-mastoid; the anterior jugular veins lie for a portion of their course in the space, and each passes outwards in the lateral recess of its own side.

From the deep surface of the sterno-mastoid muscle an important deep process of the fascia passes forwards and inwards. This process surrounds the common carotid arteries and their accompanying structures, forming a sheath for them with distinct compartments for the artery, the vein and the vagus nerve. Beyond the vessels the process divides into two, a visceral and a prevertebral layer. The visceral layer reaches the windpipe and gullet, enveloping them in front and behind, and is continued down upon them into the thorax, where it joins the fibrous layer of the pericardium. The prevertebral layer passes in front of the longus colli and the bodies of the vertebrae, and is likewise continued down into the thorax. Delicate septa, passing between the anterior portion of the visceral layer and the more superficial layer, complete the investment of the sterno-hyoid and sterno-thyroid muscles. Behind the visceral layer, between it and the prevertebral layer, is the retro-oesophageal space, which, however, is not entirely uninterrupted, but is bridged across by delicate bands of connective tissue which pass between the layers of fascia which form its walls.

Another important deep process passes from the fascia in the upper part of the neck in the region where, stretching to the zygoma, it covers the parotid gland. The deep process passes upwards on the deep surface of the parotid, completing a sheath for the gland, and investing the posterior belly of the digastric, the styloid and the pterygoid muscles. The parotid capsule is dense, and in swelling of the gland, such as occurs in the affection known as "mumps," the pressure which it exercises upon the nerves contained within the gland is frequently so great as to give rise to severe pain. The submaxillary gland is also encapsuled. In connection with the deep process which passes to the skull on the deep surface of the parotid, a number of stronger bands or ligaments are developed. The *stylo-maxillary* ligament stretches from the styloid process to the angle of the jaw, and is the strongest portion of the layer intervening between the parotid and submaxillary glands. The *spheno-maxillary* ligament, or internal lateral ligament of the lower jaw (p. 244), is similarly continuous with the fascia at its anterior and posterior borders. Two other bands, which are partly connected with the fascia, may be mentioned here. The first, the *pterygo-maxillary* ligament from the hamular process to the extremity of the mylo-hyoid ridge of the lower jaw, gives origin to the buccinator in front and a portion of the superior constrictor of the pharynx behind;

the other, the *pterygo-spinous* ligament, a band passing from the external pterygoid plate to the spine of the sphenoid, is occasionally ossified.

A thin layer of fascia in the lower part of the neck on each side forms a *cervico-thoracic septum.* It is attached to the first dorsal transverse process and the concave margin of the first rib, and forms a dome-like roof to the pleural cavity. Occasionally a few muscular fibres from one of the scalene muscles spread over it.

THE DEEP MUSCLES OF THE BACK.

Under this term may be included the whole of the muscles covered by the two posterior serrati and the vertebral and lumbar aponeurosis. The group stretches from the back of the sacrum to the skull, and the

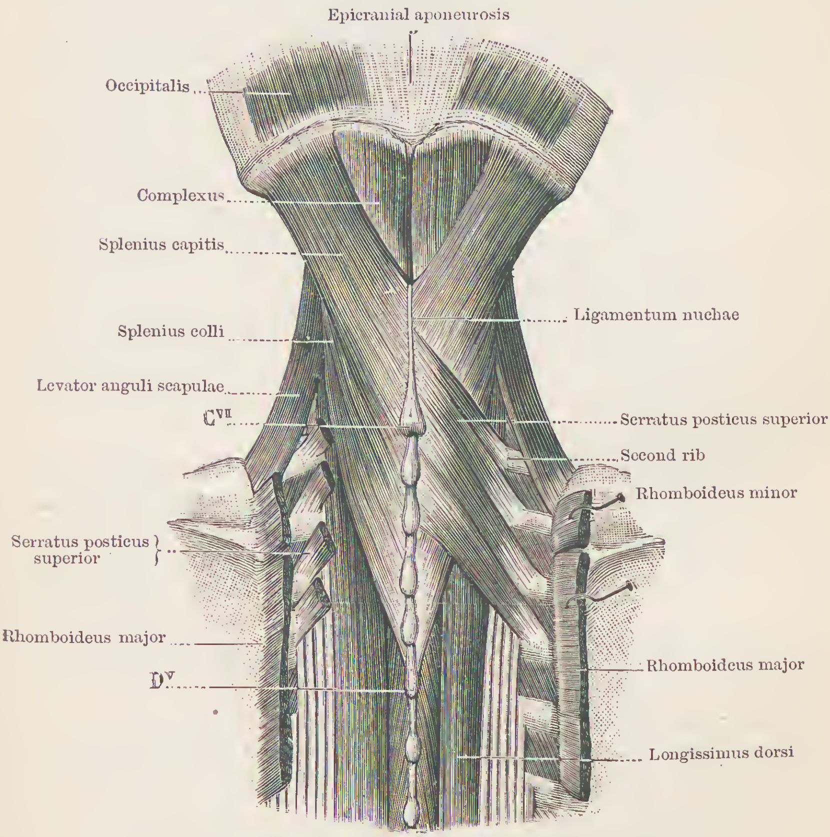


FIG. 282.—DEEP MUSCLES OF THE BACK OF THE NECK. (L. Testut.)

individual members of it are characterized by a larger number of origins and insertions, and a greater amount of normal variation, and exhibit a less perfect differentiation than most muscles. Most superficial among them are the splenius, occupying the cervical and upper thoracic regions,

and the erector spinae which extends the whole length of the trunk. Only a small slip of the erector spinae—viz., that termed trachelo-mastoid—is covered by the splenius; apart from this the splenius and erector spinae exhibit parallel borders in contact with one another. The splenius arises from cervical and upper thoracic spines, and is inserted into the skull and upper cervical transverse processes. The erector spinae, occupying the whole breadth of the space covered by the lumbar aponeurosis, arises largely from spines up to the level of the seventh thoracic, and is inserted into accessory and transverse processes and ribs and not into spines, save only to a small extent in the upper thoracic region.

On the deep surface of the splenius and erector spinae are three long muscles, the fibres of which are directed upwards and inwards, taking origin from mammillary processes and their homologues, and passing to insertion on spines. The individual muscles are distinguished from one another by the length of their fibres, and the longer fibred are the more superficial. The first, the complexus, passes from the higher thoracic transverse processes and cervical articular processes to the skull. The second, the semispinalis, from the higher ten thoracic transverse processes to spines from that of the axis to the fourth thoracic. The third, the multifidus spinae, made up of short bundles, passes from the back of the sacrum, the lumbar mammillary processes, the thoracic transverse processes, and the cervical articular processes, to the spines of all the movable vertebrae from the axis downwards. Besides the long muscles there are also numerous short muscles which pass between contiguous spines and between contiguous transverse processes in the region below the atlas vertebra. In the region between the axis and the skull there is a special group of four small muscles.

The **splenius** arises from the spines of five or six of the higher thoracic vertebrae, from that of the seventh cervical and from the ligamentum nuchae, extending in its origin as high as the third cervical spine. The upper and larger portion receives the name of *splenius capitis*, and is inserted into the mastoid process and the outer part of the superior curved line. The lower portion, the *splenius colli*, is inserted by tendons into the posterior tubercles of the transverse processes of the first three or four cervical vertebrae.

The **erector spinae** arises from the lower thoracic and all the lumbar and sacral spines, from the posterior sacro-coccygeal ligaments, from the posterior fourth of the iliac crest, and from the adjacent triangular area of the ventral surface of the ilium behind the attachment of the posterior sacro-iliac ligament. The greater part of the origin is formed by a strong flat tendon attached internally to the spines and externally to the iliac crest, and giving origin on its deep surface to fibres of the multifidus spinae; but the outermost portion of the origin from the crest and the whole of that from the ventral surface of the ilium are muscular. The muscle is composed almost entirely of two columns, each consisting of a

principal or basal part, and two successive prolongations. The basal part of the inner column is the longissimus dorsi, and its prolongations are the transversalis cervicis and the trachelo-mastoid. The basal portion of the

FIG. 283.—ERECTOR SPINAE. (L. Testut.)

outer column is the ilio-costalis, and its prolongations are the musculus accessorius and the cervicalis ascendens. At the inner margin of the longissimus dorsi there is a small additional portion, the spinalis dorsi, which extends upwards to the higher thoracic spines.

The *ilio-costalis* (*sacro-lumbalis—ilio-costalis lumborum*), the basal muscle of the outer column, is inserted by tendons into the angles of the six lower ribs, and gives a slip to the musculus accessorius.

The *musculus accessorius* (*ilio-costalis dorsi*), the second portion of the column, springs by tendons from the angles of the six lower ribs, and is inserted in like manner into the angles of the six upper ribs and the transverse process of the seventh cervical vertebra. Its tendons of origin are internal to those of insertion of the ilio-costalis.

The *cervicalis ascendens* (*ilio-costalis cervicis*), the highest portion of the outer column, receives a slip from the musculus accessorius, and springs by tendons from the angles of the sixth and three or four of the higher ribs. It is inserted by short tendons into the posterior tubercles of the transverse processes of the fourth, fifth, and sixth cervical vertebrae. Its tendons of origin are internal to those of insertion of the musculus accessorius.

The *spinalis dorsi* is a narrow set of musculo-tendinous bundles attached to the sides of the spines of the thoracic vertebrae, and passing from the lower to the higher of these. It is freely connected at its edge with the longissimus dorsi, and on its deep surface with the semispinalis muscle.

The *longissimus dorsi*, the basal muscle of the inner column, thick and fleshy, is inserted along the whole length of its outer and inner margins. Externally it is attached in the lumbar region by muscular slips to the transverse processes of the vertebrae and the intervening portions of the middle layer of the lumbar aponeurosis, and in the thoracic region by a series of delicate musculo-tendinous slips to the eight or nine lower ribs between their tubercles and their angles. Internally it is attached by a set of rounded tendons, which in the lumbar region pass to the accessory processes and in the thoracic region to the tranverse processes of all the vertebrae. Some of its fibres are continued above into the upper muscles of the column.

The *transversalis cervicis* (*longissimus cervicis*) springs by delicate tendons, placed internally to those of the longissimus dorsi, from the transverse processes of the four or five upper thoracic vertebrae and that of the last cervical. It is inserted by tendons into the posterior tubercles of the transverse processes of the cervical vertebrae from the second to the sixth.

The *trachelo-mastoid* (*longissimus capitis*), in close connection with the inner surface of the transversalis cervicis, takes origin by tendons from the transverse processes of the two or three upper thoracic vertebrae, and from the roughnesses on the sides of the articular processes of the two or three lower cervical vertebrae. It forms a thin muscular sheet, and is inserted into the posterior region of the outer surface of the mastoid process, under cover of the splenius capitis. A tendinous intersection crosses the upper part of the muscle.

The **complexus**, a strong fleshy mass, arises from the articular processes of the lower four or five cervical vertebrae, and from the transverse processes of the upper six or seven thoracic vertebrae, and at its inner

edge it usually receives a slip from one or two of the higher thoracic or lower cervical spines. It is inserted into the inner area between the two curved lines of the occipital bone. A tendinous intersection is usually

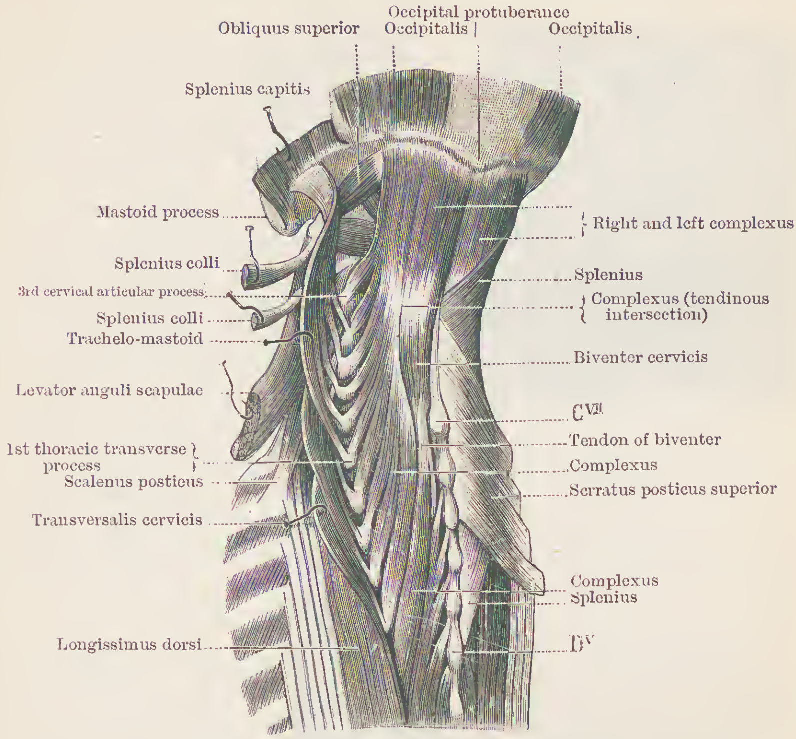


Fig. 284.—The Upper Part of the Erector Spinae and the Complexus. (L. Testut.)

found about the middle of the inner edge of the muscle, and, in consequence, the name *biventer cervicis* is sometimes given to the portion of the muscle which lies next the spines.

The **semispinalis** springs from the transverse processes of the thoracic vertebrae from the first to the tenth, and is inserted into ten spines from that of the axis downwards. The upper four or five slips show large muscular bundles springing from short tendons of origin, and, collectively, receive the name of *semispinalis colli.* The lower portion of the muscle, *semispinalis dorsi,* is made up of five or six slender muscular slips lying between long tendons of origin and insertion.

The **multifidus spinae** is formed of a large number of generally fan-shaped muscular bundles, and extends from the sacrum to the axis. In the neck the bundles arise from the articular processes of the third and succeeding vertebrae, in the thoracic region from the transverse processes, in the loins from the mammillary processes, and in the sacral region, where the bundles are blended together at their origin, the muscular fibres spring

from the hollow on the back of the sacrum extending as far as the fourth foramen, from the posterior sacro-iliac ligament, and from the overlying tendon of the erector spinae. The fibres pass to the spines of all the movable vertebrae from the axis downwards, and on each spine the insertion spreads from the base almost to the tip. The more superficial fibres of each fan-shaped bundle cross over three or four vertebrae; the deeper are successively shorter, and the deepest of all, most constant in the thoracic region, but occasionally present in the neck and loins, pass between contiguous bones. In the neck and thoracic region the bundles may be separated from one another with tolerable accuracy; but in the loins, where the muscle is thickest, the fibres of successive bundles are considerably intermixed. The more superficial or longer fibres of any one bundle overlie the deeper or shorter fibres of the neighbouring higher bundles. The deepest or shortest fibres which pass between contiguous bones are sometimes separately described under the names *rotatores dorsi* or *rotatores spinae*. The highest one or two bundles of the muscle are necessarily short.

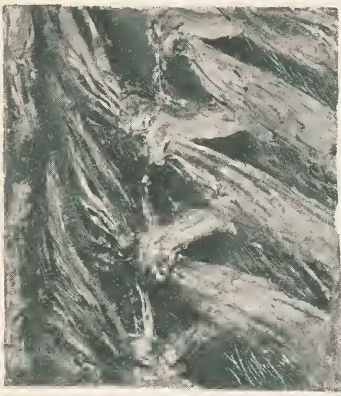


Fig. 285.—Three Bundles of the Multifidus Spinae in the Thoracic Region. *a*, Multifidus spinae; *b*, levator costae; *c*, posterior costo-transverse ligament.

The **interspinales muscles** form in the neck and loins a single set on each side of the middle line; in the thoracic region they are usually absent altogether. In the neck the muscles are rounded bundles, the highest of which is placed between the second and third vertebrae. In the lumbar regions they are thin and flattened from side to side.

The **intertransversales muscles** form in the neck and loins a double set on each side; in the thoracic region they are usually absent. The cervical muscles, anterior and posterior in position, pass respectively between successive anterior tubercles and successive posterior tubercles of transverse processes, the highest pair stretching between the atlas and the axis. The lumbar muscles are, relatively to one another, external and internal in position. The external muscles (*intertransversales laterales*) pass between successive transverse processes; the internal muscles (*intertransversales mediales*) in each case extend from the accessory process of one vertebra to the mammillary process of that immediately beneath it.

The **rectus capitis posticus major**, a fan-shaped muscle, passes from the side of the spine of the axis upwards and outwards to the outer part of the inferior curved line of the occipital bone and the underlying rough area.

The **rectus capitis posticus minor**, fan-shaped, and smaller than the last, springs from the tubercle of the posterior arch of the atlas, and

passes upwards to its insertion into the inner part of the inferior curved line and the underlying depression.

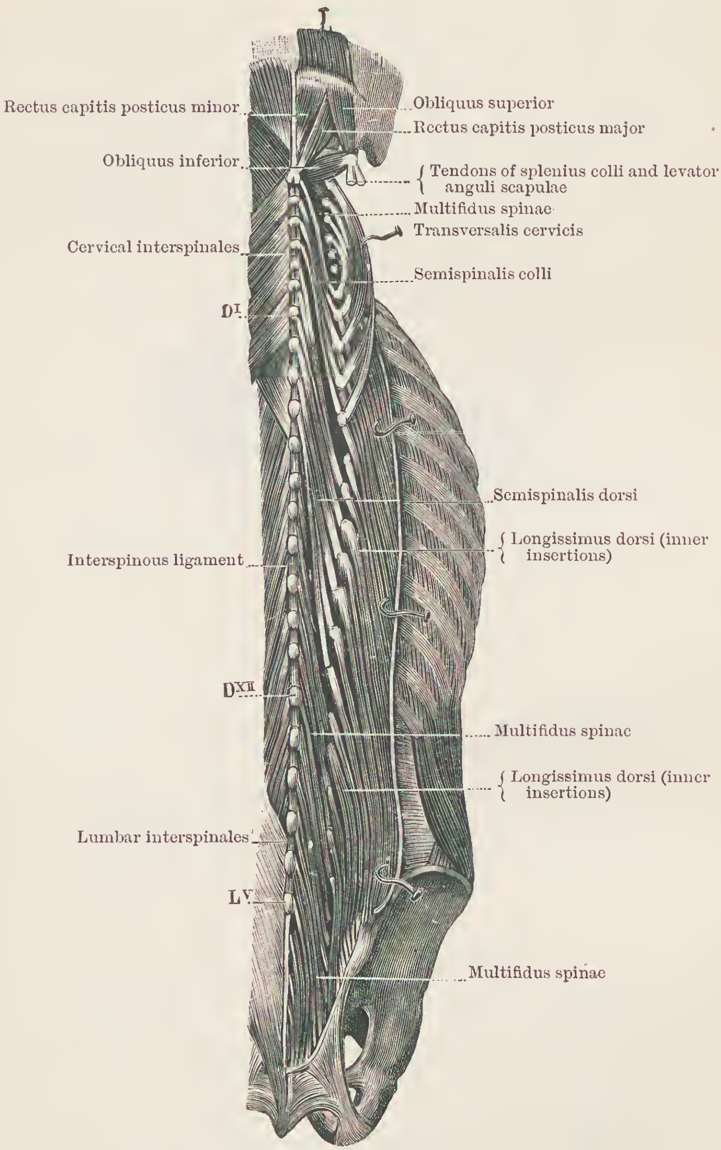


FIG. 286.—THE SEMISPINALIS AND MULTIFIDUS SPINAE. (L. Testut.)

The **obliquus capitis inferior** springs from the spine of the axis. It passes outwards and upwards to its insertion into the lower and back part of the transverse process of the atlas.

The **obliquus capitis superior** arises from the upper surface of the

transverse process of the atlas. It broadens as it passes upwards and inwards to its insertion into the outer area between the curved lines of the occipital bone.

Actions. A number of the muscles act upon the skull. By the combined action of the complexus, splenius, trachelo-mastoid, superior oblique and recti, of opposite sides, the skull is drawn backwards upon the column, and when the muscles of only one side act an oblique movement is produced; the principal elevator of the cranium is the complexus, and the principal agent in producing oblique movement the splenius. The inferior oblique of one or other side acting without its fellow produces a movement of rotation at the atlanto-axial joint, and is assisted by the splenius, trachelo-

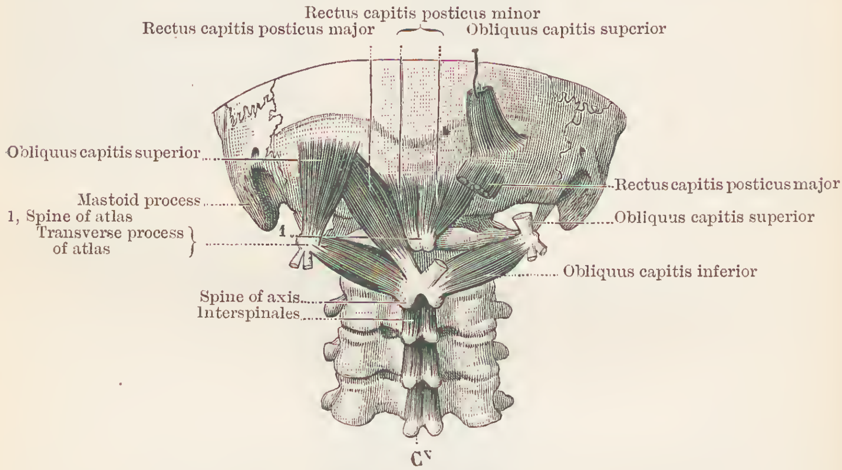


Fig. 287.—The Posterior Short Cranio-Vertebral Muscles. (L. Testut.)

mastoid, and the larger rectus of its own side. The rest of the muscles act upon the column, producing lateral curvature or extension according as those of one side only or of both sides together are brought into play.

Relations and nerve supply. The *suboccipital triangle* is the space bounded by the margins of the two oblique and the larger recti muscles; the vertebral artery, in a portion of its course, lies in it, and the suboccipital nerve, which supplies the four short posterior cranio-vertebral muscles, emerges between the artery and the atlas. The deep cervical artery lies on the deep surface of the cervical portion of the complexus, and upon the origins of the multifidus spinae muscle. Further down in the back the dorsal branches of intercostal and lumbar arteries ramify among the muscles of the group. The posterior primary divisions of the spinal nerves, dividing into external and internal branches, likewise ramify among the muscles. The external branches pass to the splenius and erector spinae; the internal branches supply the deeper muscles of the back with the exception of the cervical intertransverse and the lateral lumbar intertransverse muscles which are supplied by the anterior divisions of the nerves.

The external intertransverse muscles in the loins lie in morphological series with the levatores costarum and the external intercostal muscles in the thoracic region, and with the posterior intertransverse muscles and the rectus capitis lateralis in the neck. The anterior intertransverse muscles in the neck are in series below with the internal intercostal muscles of the thorax, and above with the rectus capitis anticus minor muscle. The internal intertransverse muscles (*intertransversales mediales*) of the loins are represented in the thoracic region probably by the inter-transverse ligaments, and are not represented in the neck.

Deep fascia of the back. In the thoracic region the deep muscles of the back are covered posteriorly by a delicate layer of fascia, *the vertebral fascia*, which extends outwards from the spines to the ribs beyond the angles and blends with the intercostal fascia. Above, it passes on the deep surface of the superior serratus and becomes blended with the deep fascia of the neck; below, it is continuous with the posterior layer of the lumbar aponeurosis.

The *lumbar aponeurosis.* Under this name three layers of fascia are described. The *posterior layer*, a strong aponeurotic sheet, is attached to the lumbar and sacral spines and to the posterior third of the iliac crest. In its lower part it becomes blended with the tendon of the erector spinae. At its outer margin it joins the middle layer and forms with it a single sheet from which a portion of the transversalis abdominis muscle is continued. In crossing outwards it covers posteriorly the deep muscles of the back and gives origin to the serratus inferior and a portion of the latissimus dorsi. The *middle layer* springs from the tips of the lumbar transverse processes and is attached above to the lower border of the last rib, and below to the ilio-lumbar ligament and the iliac crest. It passes outwards in front of the deep muscles of the back, and at the outer border of the erector spinae is joined by the posterior layer. The *anterior layer* is a more delicate sheet of fascia which covers the quadratus lumborum, and is partly blended at the outer margin of the muscle with the conjoined middle and posterior layers and partly continued into the fascia transversalis.

THE MUSCLES OF THE THORAX.

The **intercostal muscles.** In each interspace are found two layers of muscular fibres, oblique in direction, forming the external and internal intercostal muscles. Neither layer extends from end to end of the space, the external being deficient in front, the internal behind. For some distance in each space the intercostal vessels and nerves run forwards between the muscles, but near the front they sink into the substance of the inner layer.

The *external intercostals* are formed of fibres which pass from above downwards and forwards. Each muscle springs from the lower margin of a rib and is inserted into the upper margin of the rib below. The

posterior edges of the muscles reach backwards to the line of the tubercles. The anterior edges, in most cases, extend as far forwards as the line of junction of the bony ribs with the cartilages, but in the case of the first two or three fall a little short of, and in the case of a few of the lower reach a little further than this line. Continuous with the anterior edges, thin sheets of aponeurotic fibres, the *anterior intercostal aponeuroses*, extend to the extremities of the spaces.

The *internal intercostals* are not so strong as the externals, and are formed of somewhat shorter fibres, the direction of which is downwards and backwards. Each muscle springs from the cartilage and osseous rib,

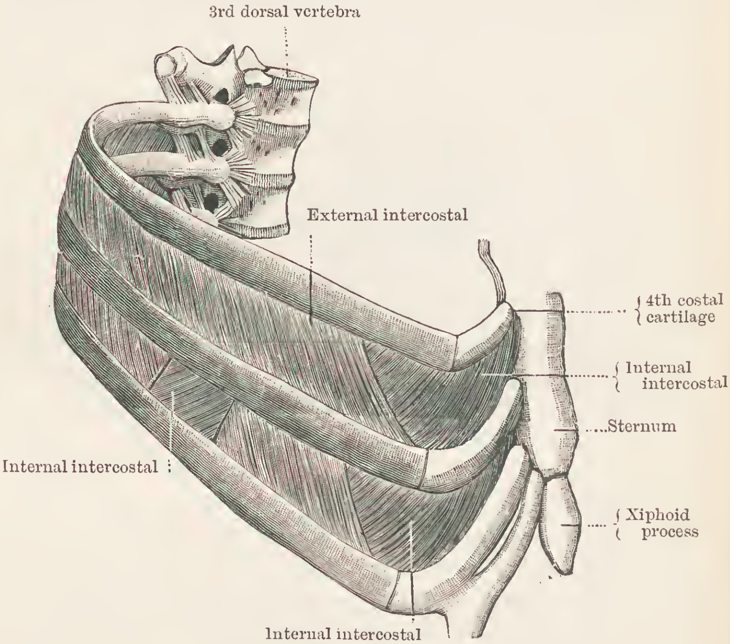


Fig. 288.—The Intercostal Muscles. (L. Testut.)

along the line of the upper margin of the subcostal groove, and is inserted into the rib below, on the inner surface close to the upper edge. The anterior edges of the muscles extend to the extremities of the spaces, and the last two are continuous in front with the internal oblique muscle. The posterior edges do not reach further backwards than the line of the angles, and, beyond this, thin sheets of fascia, the *posterior intercostal aponeuroses* line the external muscles.

Additional slips are frequently found in connection with the intercostal muscles. The name "supra-costalis" has been given to an occasional slip connected with the external muscles descending from the anterior extremity of the first rib over two or three interspaces. The "sub-costal muscles" are small variable muscular sheets placed on the inner surface of the

thoracic wall in the vicinity of the angles of the ribs; they are associated with the internal muscles and usually cross over more than one interspace. The intercostal muscles are supplied by the intercostal nerves.

The **levatores costarum**, twelve in number on each side, are small triangular muscles placed on the hinder aspect of the posterior extremities of the ribs. Each springs from the posterior surface and lower edge of the extremity of a transverse process, and passing downwards and outwards parallel to the line of an external intercostal muscle, is inserted into the upper margin and posterior surface of the rib, immediately below, in the region between the tubercle and the angle. The first springs from the transverse process of the last cervical, and the last from that of

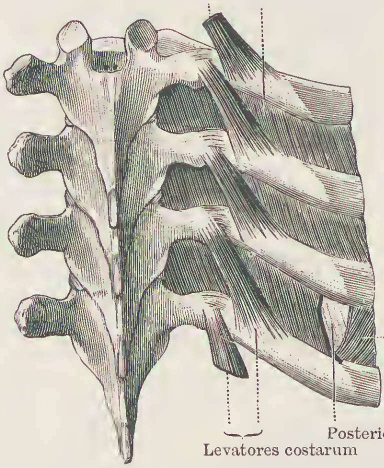


FIG. 289.—THE LEVATORES COSTARUM. (L. Testut.)

the eleventh thoracic vertebra. Near the lower end of the series a few of the muscles present additional slips which, under the name of *levatores costarum longiores*, cross over two interspaces.

The **diaphragm**, or **midriff**, is a vaulted musculo-tendinous partition which separates the thorax from the abdomen, and is pierced by the structures which pass from the one cavity to the other. The fibres arise from the front of the lumbar portion of the column, from the fascia covering the psoas and quadratus lumborum muscles, from the cartilages of the six lower ribs, and from the ensiform process of the sternum; they converge to a central tendon which forms the dome of the vault.

The *central or trefoil tendon* is formed of interwoven fibres continuous with the fleshy fibres of the muscle. It is concave posteriorly, convex and partially divided into three leaflets anteriorly—the left leaflet being the smallest, the right the largest of the three. The upper surface of the central leaflet is firmly attached to the pericardium, and rises as high as the level of the xipho-sternal articulation. The left leaflet rises to about

half an inch above the central portion, and the right, which is the highest of all, to a little more than an inch. Near the posterior margin of the tendon, in the line between the central and right leaflets, is a large somewhat four-sided aperture for the passage of the inferior vena cava.

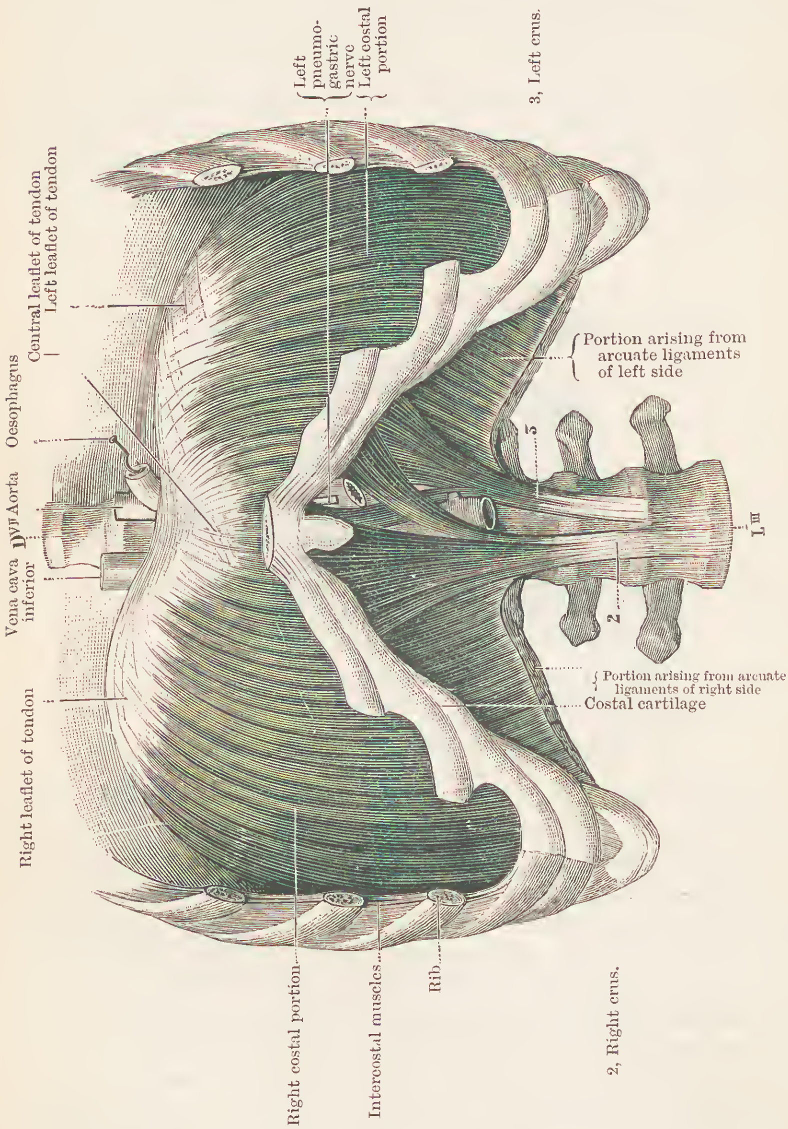


FIG. 290.—THE DIAPHRAGM, upper surface. (L. Testut.)

The *vertebral portion* of the muscle springs from two strong tendinous pillars or *crura*. The right crus, larger and broader than the other, takes origin from the anterior surface of the bodies of the first three lumbar vertebrae and the intervening discs; the left is confined to the first two lumbar bodies and the disc between them. The fibres from the crura

converge and partially decussate with one another, and finally reach the median portion of the posterior margin of the central tendon. Opposite

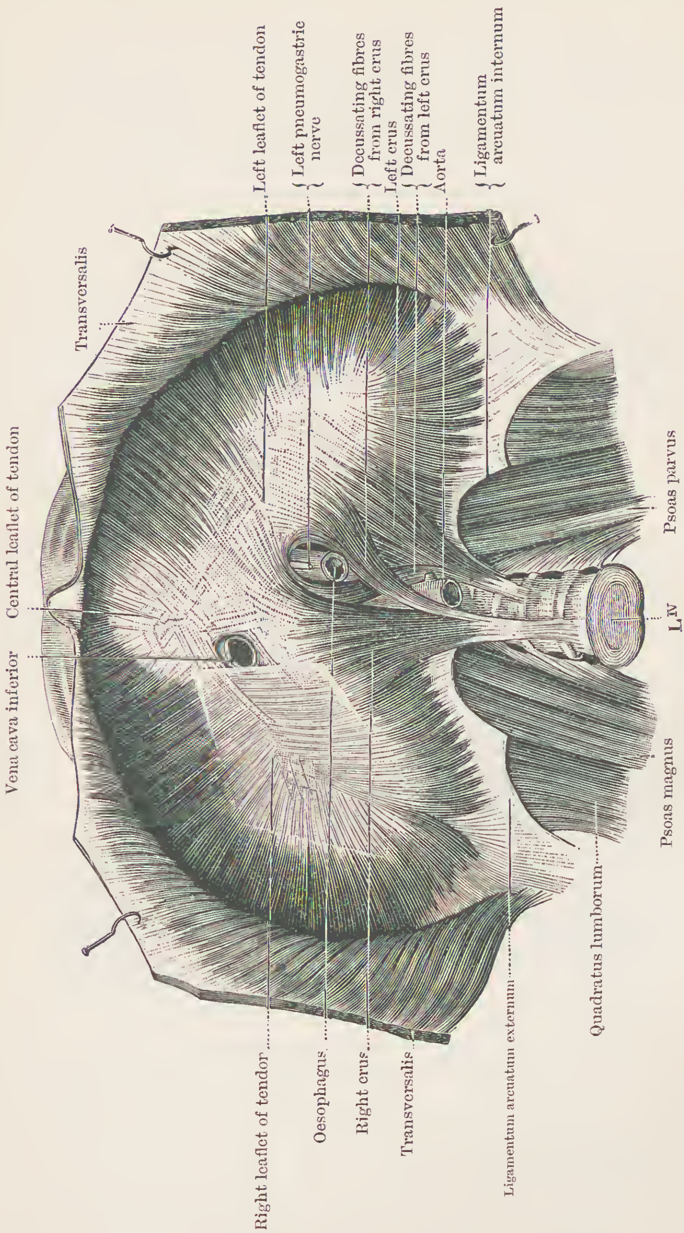


Fig. 291.—The Diaphragm, under surface. (L. Testut.)

the disc between the last dorsal and first lumbar vertebrae, the vertebral portion of the muscle presents an opening which transmits the aorta, and, in addition, the thoracic duct and, usually, the great azygos vein. The lateral

margins of the opening are formed by the tendinous fibres of each crus, and posteriorly a few fibres cross between the crura behind the aorta. A little above, and somewhat to the left of the aortic opening, is an aperture for the passage of the oesophagus and the pneumogastric nerves. The aperture is elongated from before backwards, and is usually entirely pounded by the decussating fleshy fibres from the pillars, those from the right passing generally in front of those from the left. In addition, the vertebral portions of the diaphragm are generally pierced by the splanchnic nerves, the lesser azygos vein, and, occasionally, by the main cords of the sympathetic.

The *ligamenta arcuata* are thickened bands of the fascia lining the abdominal wall. The internal stretches from the body to the tranverse process of the first lumbar vertebra arching over the psoas muscle; the external extends from the first lumbar transverse process to the last rib, near its point, arching over the quadratus lumborum muscle. The fibres from these bands, forming on each side a broad thin portion of the muscle, pass to the posterior margins of the lateral leaflets of the tendon. The sympathetic cord usually passes under the internal, and the last dorsal nerve under the external arched ligament.

The *costal portion* of the muscle springs on each side by six fleshy slips from the inner surfaces of the six lower ribs, chiefly from the cartilages, but to a slight extent also from the bones. The slips inter digitate with the slips of the transversalis abdominis muscle. The muscular fibres arch upwards to the lateral and anterior margins of the central tendon, those from the eighth and ninth ribs being the longest.

The *sternal portion* is formed by a slender fasciculus, sometimes divided into two, the fibres of which are the shortest of the whole muscle. It passes from the back of the ensiform process to the anterior margin of the central leaflet. Between the sternal and costal portions an interval is left on each side, through which the superior epigastric artery passes from the thoracic to the abdominal wall, and at which the lining membranes of the two cavities come into contact.

The diaphragm is supplied by the phrenic nerves from the cervical plexus.

The **triangularis sterni** (*transversus thoracis*) is formed of a number of delicate slips in series with those of the transversalis abdominis muscle. It arises on each side from the back of the lower part of the sternum, extending upwards in its origin as far as the level of the third costal cartilage. The slips are inserted into the lower edges and posterior surfaces of the costal cartilages from the second to the sixth, the highest, however, having a partial attachment to the bony rib. The upper slips are almost vertical in direction, the lower transverse. The muscle lies behind the internal mammary artery in a portion of its course. It is very variable in size and is sometimes absent altogether. The triangularis receives its supply from intercostal nerves.

The **serratus posticus superior** (Fig. 282) arises by a thin flat tendon from the lower part of the ligamentum nuchae, the last cervical and the first two or three thoracic spines. It passes downwards and outwards as a thin sheet, and immediately beyond the lateral margin of the erector spinae is inserted into the outer surfaces and upper borders of four ribs from the second to the fifth, and into the fascia covering the corresponding intercostal spaces. The muscle lies on the deep surface of the

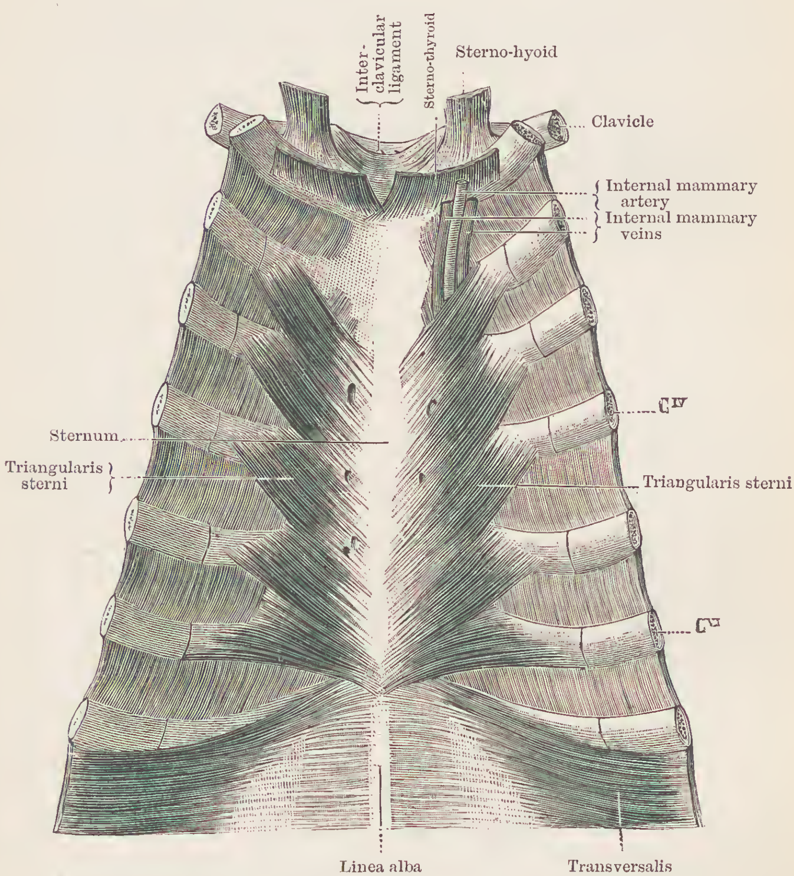


Fig. 292.—The Triangularis Sterni. (L. Testut.)

rhomboidei, and is completely covered by them, except at the upper part of the origin where it comes into contact with the deep surface of the trapezius.

The **serratus posticus inferior** (Fig. 229) arises, under cover of the latissimus dorsi, from the posterior layer of the lumbar aponeurosis in the region between the tenth thoracic and fourth lumbar spines. It is inserted by four slips into the lower borders of the last four ribs. The slips of insertion extend outwards from the border of the erector spinae

muscle as far as the margins of the costal slips of the latissimus dorsi. The first slightly overlaps the second, the third is considerably overlapped by the second, and in many cases the last is almost completely concealed by the third.

The two posterior serrati muscles are supplied by intercostal nerves.

Actions of the muscles of the thorax. Air is drawn into the lungs by the enlargement of the cavity of the thorax consequent upon the action of the muscles attached to and forming its walls. The enlargement is produced by the descent of the diaphragm and by the movements of the costal arches. The movements of the ribs have already been described (p. 128).

The central portion of the tendon of the *diaphragm* is attached to the pericardium, and, undergoing little or no alteration in position, leaves the heart undisturbed; but the muscular fibres are straightened by contraction, and their peripheral parts are thereby separated from the thoracic wall. In this way the costo-phrenic space is opened up, and into it the bases of the lungs are drawn, while the abdominal viscera are displaced downwards. The *serratus posticus inferior* draws backwards the four lower ribs, and, along with other muscles, affords resistance to the costal portion of the diaphragm, and thus enables it in contracting to concentrate its action upon the thoracic floor. The *serratus posticus superior* and the *levatores costarum* elevate the ribs and take part in inspiration. The *triangularis sterni* depresses the ribs and takes part in forced expiration.

The action of the *intercostal muscles* has been the subject of much controversy. According to Haller the external and internal muscles have a common action. It is nevertheless geometrically true that if two rods, maintained parallel to one another, are attached at one end to a vertical bar (representing the vertebral column), so as to be capable of upward and downward movement, and if points be marked on each to represent the attachments of the fibres of the external and internal intercostals, the fibres of the external muscles will be seen to be shortened by the elevation and those of the internal by the depression of the rods. This is the foundation of the view originated by Hamberger, that the external intercostals are muscles of inspiration and the internal muscles of expiration. Hutchinson (*Cyclopaedia of Anatomy and Physiology*, 1852) pointed out, that in as far as the region of the costal cartilages is concerned, the sternum must be considered the upright bar on which the movement takes place. He regarded therefore the anterior portions of the internal intercostals as elevators of the ribs, and inspiratory in function, and in this saw an explanation of the absence of the external intercostal muscles in front, and of the internal muscles posteriorly, muscular effort being specially required in inspiration. The geometrical arguments of Hamberger and Hutchinson necessitate the supposition that the successive ribs remain parallel to one another in all phases of movements, but in the dead body it may be seen that two contiguous ribs may be forced apart or drawn together without the simultaneous elevation or depression of both.

The two layers of muscles acting together would tend to approximate the ribs in series to the more fixed extremity of the thorax. In ordinary inspiration an actual approximation takes place in the case of the first and second spaces, the first rib remaining practically stationary, the second and third being elevated; and in the succeeding spaces it seems probable that, in the altered conditions brought about by the elevation of the upper ribs, the contraction of both layers of muscles would be required to maintain the parallelism of the ribs and support the thoracic wall. As the successive ribs are being elevated together the fibres of the internal intercostals will, from their direction, tend to be stretched, but the slight eversion of the lower border of the greater part of the rib which takes place during the movement will have a counterbalancing effect. In forced expiration, when the lower ribs are fixed by the contraction of the muscles of the abdominal wall, contraction of the intercostal muscles of the lower spaces will tend to diminish the size of the thoracic cavity.

In full inspiration a number of additional muscles are called into action. The vertebral column is extended; the sternum and the first and following ribs are elevated by the sterno-mastoid and scaleni muscles. In forced inspiration, with the arms fixed, the pectoralis minor and parts of the pectoralis major and serratus magnus, give powerful assistance. In ordinary expiration little or no muscular effort is required, the natural elasticity of parts bringing about recoil. In forced expiration the vertebral column is flexed, and the muscles which act upon the lower ribs, particularly those of the abdominal wall, are called into play: the triangularis sterni and possibly also the lower intercostals assist.

MUSCLES AND FASCIA OF THE ABDOMEN.

The cavity is separated from the thorax by the diaphragm, below it passes into the pelvis. The wall is partly formed by ribs, vertebral column, and pelvic bones, and is completed by various muscles and fasciae. The anterior and lateral portions of the wall are chiefly formed by three broad muscles on each side superimposed upon one another, named, from without inwards, respectively the external oblique, the internal oblique, and the transversalis. Over the lateral area of the wall they are fleshy, but in front they pass into thin expanded tendons, which meet in the middle line with one another, and with the similarly united tendons of the opposite side in a raphe which extends from the ensiform process to the upper margin of the symphysis pubis, and is named the *linea alba.* A cicatricial depression a little below the middle of this line is named the *umbilicus.* A long, vertically placed muscle, the rectus abdominis, lies by the side of the linea alba, and is inclosed in a sheath which is formed by the separation into two layers of the tendon of the internal oblique, one portion strengthened by junction

with the tendon of the external oblique passing in front of the muscle, the other incorporated with that of the transversalis passing behind. In the lower part of the anterior wall of the sheath lies a small muscle, the pyramidalis. The *lineae semilunares* are two indistinct lines seen from the front when the fascia has been removed, marking the outer edges of the recti muscles. The *lineae tranversae,* three or four in number on each side, cross from each linea semilunaris to the linea alba; they mark the position of tendinous intersections in the substance of the recti muscles.

The posterior border of the external oblique is sometimes overlapped by the outer edge of the latissimus dorsi muscle, but frequently a narrow interval is left between them in which a few of the posterior fibres of the internal oblique are exposed, and through which there occasionally occurs a protrusion of abdominal viscera, a "lumbar hernia." The posterior edges of the broad muscles reach as far back as a line drawn from the last rib near its point to the iliac crest at the junction of the posterior third with the anterior two-thirds, and behind this line the posterior wall of the abdominal cavity is formed by a thin muscle, the quadratus lumborum, which stretches between the last rib above and the ilio-lumbar ligament and the iliac crest below, and reaches as far inwards as the extremities of the transverse processes. On the anterior surfaces of the transverse processes and sides of the vertebral bodies lies the psoas magnus, along with which the psoas parvus, an occasional muscle, is sometimes found. The venter of the ilium is clothed by the iliacus muscle. A strong layer of aponeurosis, the middle layer of the lumbar aponeurosis, attached to the tips of the transverse processes, stretches outwards behind the quadratus lumborum. At the outer border of the erector spinae muscle it is united with the posterior layer of the lumbar aponeurosis which sweeps outwards from the spines, and the incorporated layers of fascia are continued into the transversalis muscle, affording it a portion of its origin.

The inner surface of the abdominal wall is everywhere lined by a continuous sheet of fascia, for the most part delicate, but strengthened at places, and receiving different names in the different regions which it covers. On the deep surface of the anterior and lateral part of the wall it is called *transversalis fascia*; on the quadratus lumborum it is known as the *anterior layer of the lumbar aponeurosis.* On the iliacus muscle and upon the psoas and the vertebral bodies it is named *iliac fascia.* Above, the fascia forms a thin layer which lines the diaphragm; below, it is fixed to the margin of the true pelvis, and is continued downwards as the pelvic fascia.

The lower margin of the anterior abdominal wall corresponds to a line drawn inwards and downwards from the anterior superior spine of the ilium to the extremity of the first half inch of the ilio-pectineal line, and continued inwards and forwards along the first half-inch of the ilio-pectineal line and the spine and crest of the pubis to the symphysis. The lower border of the aponeurosis of insertion of the external oblique

muscle stretches between the anterior superior spine and the extremity of the first half-inch of the ilio-pectineal line, and further inwards is attached to the spine and crest of the pubis. With the lower margin of the aponeurosis are incorporated the other constituents of the anterior abdominal wall. When the thigh is extended, the fascia lata being uncut, some of the lower fibres of the aponeurosis of the muscle are brought into special prominence and give the appearance of a band stretching from the anterior superior spine to the spine of the pubis. The band thus made prominent is *Poupart's ligament*; it forms an important surgical

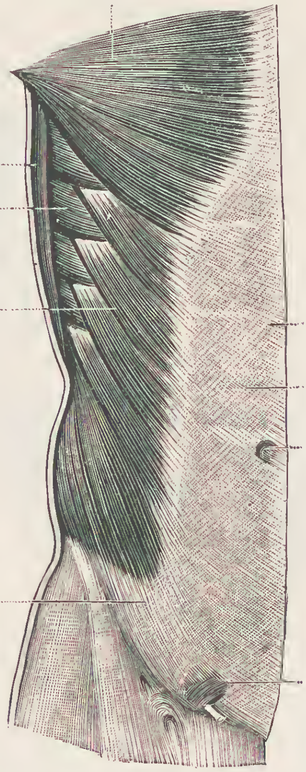


FIG. 293.—THE EXTERNAL OBLIQUE MUSCLE. (L. Testut.)

landmark. The great vessels which pass between the abdomen and the thigh lie behind Poupart's ligament, and by their inner side there is a small blind pouch into which a protrusion known as a "femoral hernia" occasionally occurs.

The lower part of the anterior abdominal wall is traversed by an oblique passage, the *inguinal canal*, which transmits in the male the spermatic cord and in the female the round ligament of the uterus. The inner opening of the canal is known as the *internal or deep abdominal ring*, and is placed about half an inch above the middle of Poupart's

ligament. The *external or superficial ring* lies immediately above the spine of the pubis. A hernial protrusion along this canal is called an "inguinal hernia."

The **external oblique** has a broad origin from the outer surfaces of the eight lower ribs, by fleshy slips which interdigitate, the higher with those of the serratus magnus, the lower with those of the latissimus dorsi. The muscular fibres from the last two ribs pass almost directly downwards to the outer lip of the anterior half of the iliac crest, the others are directed inwards and downwards to a broad aponeurosis which forms the tendon of insertion.

The aponeurosis of the external oblique covers the anterior part of the abdominal wall. It consists for the most part of parallel, obliquely descending, fibres passing inwards in front of the rectus muscle to the linea alba. Its lower edge is stretched from the anterior superior iliac spine to the first half-inch of the ilio-pectineal line and the spine and crest of the pubis, where it is attached along a continuous line. It is described under the names of "Poupart's ligament" and "Gimbernat's ligament."

Poupart's ligament, or the *superficial crural arch*, is the band of fibres brought into prominence when the thigh with the fascia lata intact is extended and rotated outwards. It stretches from the anterior superior spine to the spine of the pubis. In its outer three-fourths it contains all the fibres of the lower edge of the aponeurosis of insertion of the external oblique, but in its inner fourth only the more superficial, those which form the band attached to the pubic spine. *Gimbernat's* ligament is formed by the deeper fibres which pass from the inner fourth of Poupart's ligament to insertion into the first half-inch of the ilio-pectineal line. Muscular fibres of the internal oblique and transversalis muscles spring from the outer part of Poupart's ligament, and, more internally, the conjoined tendon of the two muscles is attached to the deep surface of the ligament, and is continued along with Gimbernat's ligament to the ilio-pectineal line. Deeper still, the fascia transversalis is fixed to the back of Poupart's ligament, and at its inner part is closely associated with Gimbernat's ligament and the conjoined tendon. The fascia iliaca blends with the fascia transversalis on the deep surface of the outer half of Poupart's ligament; further inwards the two fasciae are separated from one another by the great vessels, but still further inwards they again meet at the outer edge of Gimbernat's ligament. The iliac portion of the fascia lata is attached to the lower edge of Poupart's ligament, and the pubic portion of the same fascia is fixed to the ilio-pectineal line along the line of attachment of Gimbernat's ligament. To the anterior surface of Poupart's ligament is attached the fascia of Scarpa, the deep layer of the superficial fascia of the lower part of the anterior abdominal wall.

The *external or superficial abdominal ring* is an opening in the lower part of the tendon of the external oblique for the passage of the spermatic cord and its associated structures in the male, or the round ligament of the

uterus in the female. The opening is a narrow space left between the fibres attached to the crest of the pubis and those which are attached to the spine. The margins of the aperture are called the *columns* or *pillars* of the ring. Some of the fibres of the inner pillar decussate on the front of the symphysis, with corresponding fibres from the opposite side. The opening is triangular in shape, the base being on the crest of the pubis, and the apex half an inch distant, a little above and a little external to the spine. The pillars are bound to one another by a delicate sheet of transverse or intercolumnar fibres which is prolonged, under the name of the *intercolumnar or spermatic fascia,* as a covering to the structures which pass through the ring. The cord or round ligament, in passing through, lies upon the lower or outer pillar, in immediate proximity to the outer edge of the spine. Some fibres which pass inwards from Gimbernat's ligament

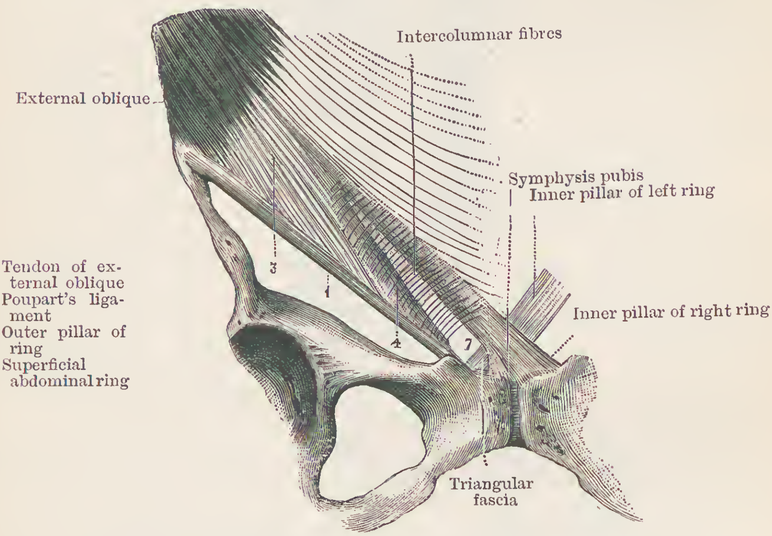


FIG. 294.—THE SUPERFICIAL ABDOMINAL RING (diagrammatic). (L. Testut.)

cross the floor of the ring, passing behind the inner pillar to reach the front of the sheath of the rectus, where they are associated with the fibres of the inner pillar of the opposite side. They are very variable in the extent of their development and are named the *triangular fascia.*

The **internal oblique** arises by fleshy fibres, which are directed inwards, the upper passing, in addition, obliquely upwards, the lowest having a slight direction downwards. They spring from the middle area of the anterior two-thirds of the iliac crest, and from the outer half of Poupart's ligament. At the upper and posterior border a few fibres take origin from the lumbar aponeurosis. The upper fibres are attached to the lower borders of the cartilages of the last four ribs, and lie at their insertion in the same plane as the internal intercostal muscles. Those next in order pass into a broad aponeurosis which begins about an inch from the

margin of the rectus muscle, and sweeps inwards to the linea alba, splitting as it reaches the muscle to assist in forming its sheath; the anterior layer blends with the tendon of the external oblique, the posterior with that of the transversalis. The lowest fibres, joining with the lowest of the

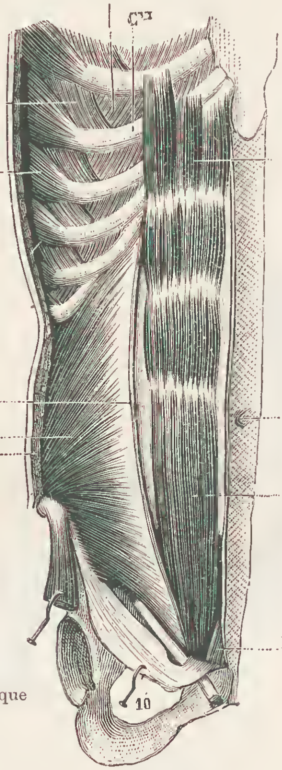


FIG. 295.—THE INTERNAL OBLIQUE AND RECTUS MUSCLES. (L. Testut.)

transversalis muscle, are inserted along with them by the conjoined tendon into the first half-inch of the ilio-pectineal line, and into Gimbernat's and a portion of Poupart's ligament. The lower border of the muscle crosses in front of the inguinal canal.

The **cremaster** represents a continuation downwards of a few of the lower fibres of the internal oblique, and is much better developed in the male than in the female. It springs from Poupart's ligament at the lower margin of the internal oblique, and in the male its fibres descend in front of the cord; many of them form loops, and pass backwards to an inner insertion on the spine of the pubis, but others reaching further down are lost in a fascia, the *cremasteric fascia*, which invests the cord and the testicle. In the female a few fibres representing the muscle are usually found descending in front of the round ligament.

The **transversalis** has a broad origin, and its fibres are directed

inwards, the lowest however, having, in addition, an inclination downwards. It springs (*a*) from the inner surfaces of the cartilages of the six lower ribs by fleshy slips which interdigitate with those of the diaphragm, (*b*) in the region between the last rib and the iliac crest, from the lumbar aponeurosis, (*c*) from the inner lip of the anterior half of the iliac crest, and (*d*) from the outer third of Poupart's ligament. All, except the lowest fibres, pass into a broad aponeurosis, which, joining the posterior layer of the aponeurosis of the internal oblique, sweeps towards the linea alba, and assists in forming the sheath of the rectus. Along the greater part of its length the aponeurosis begins about an inch from the margin of the rectus, but above it is narrow, and there the muscular fibres extend inwards for a little distance behind the sheath. The lowest fibres, closely associated with those of the internal oblique, pass into the conjoined tendon. Between the internal oblique and transversalis muscles run some of the lower dorsal and upper lumbar nerves, the lumbar arteries, and a branch of the deep circumflex iliac artery.

The *conjoined tendon*, which receives the lowest fibres of the internal oblique and transversalis muscles, begins close to the inner and upper margin of the deep abdominal ring, and in passing downwards to its insertion is crossed in front, obliquely from without inwards, by the cord or round ligament. It is blended below with the deep surface of Poupart's and Gimbernat's ligament, and along with the latter is attached to the first half-inch of the ilio-pectineal line; its outer margin reaches as far outwards as the middle of Poupart's ligament. Its outer border circumscribes the inner and lower margins of the deep ring, and is chiefly composed of fibres derived from the transversalis muscle. The middle portion of the tendon is the weakest, while the inner portion, descending to the ilio-pectineal line, is the strongest and best marked. The fascia transversalis is closely united to the deep surface of the tendon, but may, in a well-developed subject, be separated from it by careful dissection. The outer margin of the tendon, which surrounds the lower and inner sides of the deep ring, has sometimes been described under the name of the "reflected tendon of Sir Astley Cooper." Occasionally muscular fibres belonging to the two muscles descend upon the whole breadth of the tendon to the insertion. (Mackay, 1889.)

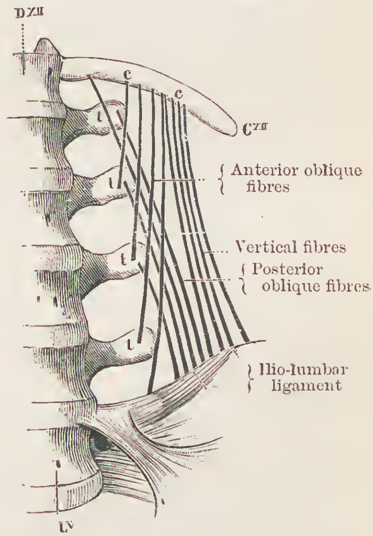


FIG. 296.—ARRANGEMENT OF THE FIBRES OF THE QUADRATUS LUMBORUM (diagram.) (L. Testut.)

The **quadratus lumborum** arises from the ilio-lumbar ligament and

the inner lip of the iliac crest for about an inch beyond the attachment of the ligament. The outermost fibres are directed upwards and slightly inwards to the lower edge of the last rib, and those more internal, passing with more and more obliquity, are inserted into the transverse processes of the first four lumbar vertebrae. An additional set of fibres at the inner edge and on the anterior surface of the muscle springs from the transverse processes of the three lower lumbar vertebrae, and is inserted with the outer part of the muscle into the last rib and first lumbar transverse process.

The **rectus abdominis**, strap-shaped, springs from the anterior surface and the upper border of the body of the pubic bone by a strong tendon partially divided into two. The inner portion of the tendon arises from the whole anterior surface of the symphysis, and is at its inner edge continuous with the corresponding tendon of the muscle of the opposite side; the outer portion is attached to the crest. At the upper end the muscle is inserted by three slips, the outermost to the lower border of the fifth rib immediately external to the cartilage, the other two to the anterior surfaces of the cartilages of the sixth and seventh ribs respectively. In the course of the muscle three tendinous intersections are commonly found; the first is usually placed opposite the articulation between the ninth and tenth costal cartilages, the second about an inch above the umbilicus, and the third about half an inch below the umbilicus. These do not as a rule penetrate the whole thickness of the muscular substance, but are confined to the anterior surface, and are intimately adherent to the anterior wall of the sheath. They may extend beyond the rectus into the substance of the internal oblique, and they occasionally appear to be continued from the extremities of some of the lower ribs. Additional ones are sometimes present.

The **pyramidalis** is a small triangular muscle, of an inch to two inches in length, contained in the anterior wall of the sheath of the rectus. It arises from the anterior surface of the pubis, and, becoming narrower as it ascends, is inserted into the linea alba. The muscle is frequently absent on one or both sides.

The *sheath of the rectus.* Close to the margin of the rectus the aponeurosis of insertion of the internal oblique splits into two layers, the anterior of which blends with the aponeurosis of the external oblique, the posterior with that of the transversalis. These pass to the linea alba, inclosing the rectus between them. The anterior wall of the sheath, moderately strong in the greater part of its extent, becomes thinner above where it is continued into the deep fascia of the chest wall; some fibres of the pectoralis major spring from it. At its lower end the pyramidalis is embedded in it. On its posterior aspect it is closely united to the tendinous intersections of the rectus muscle.

The posterior wall of the sheath is strong in its upper two-thirds, and is fixed above to the margins of the cartilages of the sixth, seventh,

and eighth ribs. In its lower part, below a line drawn between the most prominent parts of the iliac crests of the opposite sides, it is very weak, most of the fibres of the internal oblique and many of those of the transversalis passing to the anterior wall of the sheath. The lower edge of the strong upper portion, lying a little below the umbilicus, is often marked as a distinct curved line, the *semilunar fold of Douglas.* A second semilunar fold, a little nearer the pubis, is often present, marking the spot where the deep epigastric artery enters the sheath; it has been named the *band of Henle.*

The *linea alba* is formed by the decussation of the tendinous fibres of the aponeuroses of the three broad muscles of the abdominal wall. It extends from the xiphoid process of the sternum to the pubis. It is somewhat broader above than below, and is pierced by numerous apertures for the passage of small vessels. The superficial fascia is adherent to it in front, the fascia transversalis behind.

The *umbilicus* or *navel* is the mark left by the withering of the umbilical cord after birth. It is placed a little below the middle of the linea alba. From the front it appears as a somewhat rounded hollow, behind as a much smaller transversely elongated depression. It is occupied by some cicatricial and fatty tissue, by the urachus with the obliterated hypogastric arteries, and by the umbilical vein. The lower part of the space contains the urachus and the remains of the arteries, and is filled up by cicatricial tissue. The upper part of the space, much weaker, contains the remains of the vein surrounded by fatty tissue, which is continuous with the subcutaneous fat. Through the weak upper portion a hernial protrusion may take place.

Actions of the abdominal muscles. Acting from below they flex the vertebral column, depress the lower ribs, and exercise pressure upon the abdominal viscera. They assist powerfully in producing the evacuation of the contents of hollow viscera, and play an important part in the movements of forced expiration. The muscles of one side, acting alone, can bring about lateral flexion of the column. The quadratus lumborum has but little direct action upon the viscera, but assists in producing lateral flexure of the column; it draws downwards the last rib, and, on account of its antagonism to the diaphragm, has been regarded by some as an agent in inspiration. When the thorax and upper part of the column are fixed the abdominal muscles of one or both sides may, by acting upon the lower part of the column, raise the pelvis.

Nerves. The muscles are supplied by the lower dorsal nerves, and by the upper branches of the lumbar plexus. The muscles which receive supply from lumbar nerves are the pyramidalis and the lower parts of the internal oblique and transversalis, which receive branches from the ilio-hypogastric and ilio-inguinal nerves, and the cremaster which is supplied by the genital branch of the genito-crural.

ABDOMINAL FASCIA.

The deeper layer of the *superficial fascia*, at the lower part of the anterior wall, goes by the name of the *fascia of Scarpa*. Scarpa's fascia is firmly fixed to Poupart's ligament, extending as far inwards as the superficial abdominal ring. On account of this attachment, fluid which has been effused under the superficial fascia of the abdomen is prevented access into the thigh. At the ring the fascia passes downwards over the cord, or in the female the round ligament, and becomes continuous with the superficial tissue of the scrotum or labium, according to the sex. The superficial tissue of the scrotum is named the *dartos* tunic or fascia; it has a reddish colour, and contains a number of involuntary muscular fibres. It is continuous behind with Colles' fascia, the superficial fascia of the anterior part of the perineum. Along the middle line of the abdomen the superficial fascia is fixed to the linea alba, and is continued below into the superficial fascia of the penis, which, like the dartos, contains a few involuntary muscular fibres, but is devoid of fat. A strengthened portion from the lower part of the linea alba and the symphysis attached to the dorsum of the penis near the root constitutes the *suspensory ligament of the penis*.

A very thin *deep layer of fascia* lies close on the surface of the external oblique muscle, and becomes blended with its tendon at the lower part of the anterior abdominal wall, taking part in the formation of the intercolumnar fascia.

The **lining fascia of the abdomen.** The anterior surface of the quadratus lumborum muscle is covered by a moderately strong layer of fascia, which goes by the name of the *anterior layer of the lumbar aponeurosis*. At its inner margin it is attached to the transverse processes of the lumbar vertebrae, and blends with the upward prolongation of the iliac fascia, which covers the psoas muscle; at its outer edge it is partly continued into the transversalis fascia on the deep surface of the transversalis muscle, and partly into the aponeurotic sheet formed by the union of the posterior and middle layers of the lumbar aponeurosis which forms the posterior tendon of the transversalis muscle. Below, it is fixed to the iliac crest; above, it passes as a very thin layer on to the diaphragm. A strengthened band, the *ligamentum arcuatum externum*, arches from the transverse process of the first or second lumbar vertebra to the inner surface of the last rib near its point, crossing the quadratus muscle and giving origin to a number of the fibres of the diaphragm.

The *iliac fascia*, which below covers the iliacus muscle, is continued upwards as a fine layer over the surface of the psoas muscle, and spreads thence to the diaphragm, and is attached externally to the transverse processes, and internally to the vertebral bodies and intervertebral discs. Between the body and the transverse process of the first lumbar vertebra the fascia is strengthened in the form of a fibrous band, the *ligamentum arcuatum internum*, which gives origin to a number of the fibres of the

diaphragm. The ligament has an occasional additional attachment to the transverse process of the second lumbar vertebra. At the lower part of the abdomen the fascia is stronger where it spreads over the iliacus muscle, and is attached externally to the iliac crest and internally to the ilio-pectineal line. It furnishes a delicate investment to the external iliac vessels, and behind them is continued into the thigh, forming the posterior wall of the femoral sheath and blending with the deep prolongation of the pubic portion of the fascia lata on the ilio-psoas and pectineus muscles. The lower border of the fascia in the region external to the vessels is attached to the deep surface of Poupart's ligament, where it meets the fascia transversalis. Abscesses connected with carious vertebrae, even when the disease is limited to the dorsal region, may pass downwards in the substance of the psoas muscle and reach the thigh under cover of the prolongation of the iliac fascia.

The *fascia transversalis* is a thin sheet which lines the deep surface of the transversalis muscle, and is continuous with the fascia covering the quadratus lumborum and the delicate layer on the under surface of the diaphragm. Anteriorly it is attached to the linea alba. Below, in the middle line, it passes behind the symphysis into the pelvis; further outwards it is attached to the deep surface of the conjoined tendon and Gimbernat's ligament, and still more externally to Poupart's ligament and the iliac crest. In the region immediately external to Gimbernat's ligament it is arched over the vessels, and is prolonged into the thigh as the main part of the anterior wall of the femoral sheath. Beyond the artery it meets, on the deep surface of Poupart's ligament, the fascia iliaca.

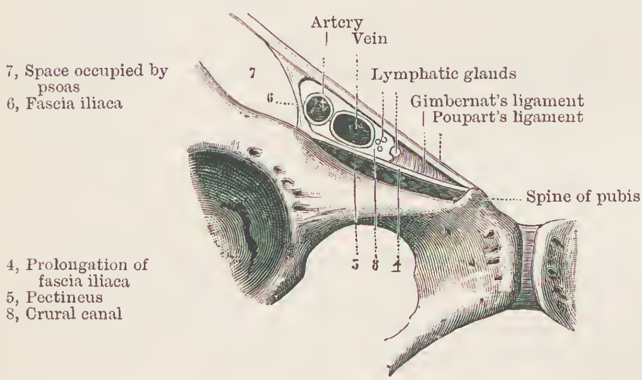


FIG. 297.—DIAGRAM OF THE CRURAL ARCH. (L. Testut.)

The *crural canal and femoral hernia.* The vessels which pass between the abdomen and the thigh receive in the abdominal portion of their course from the fascia iliaca upon which they lie, a delicate investment surrounding and separating them; but as they pass into the thigh there is added to this a moderately strong sheath, prolonged from the fascia transversalis in front and the fascia iliaca behind. At the place of exit of the vessels the sheath

is somewhat larger than is necessary to contain them, and a space, sufficient in size to admit the little finger, is left between the vein, which is the inner of the two vessels, and the edge of Gimbernat's ligament. The sheath rapidly narrows, and the space is continued downwards for but a short distance—about half an inch—into the thigh, and terminates in a pointed blind extremity. The space is the *crural canal*; it occasionally gives passage to a protrusion of abdominal viscera known as a "femoral hernia." In the normal state it is occupied by one or two small lymphatic glands and some subperitoneal tissue which constitute the *septum crurale.* The abdominal opening of the canal is bounded internally and anteriorly by Gimbernat's ligament, to which the fascia transversalis is attached, externally by the vein, a delicate septum intervening, and posteriorly by the pectineus muscle clothed by the prolongation of the fascia iliaca into the deep portion of the fascia lata of the thigh. Immediately above the anterior margin the spermatic cord or round ligament passes obliquely downwards. In very rare cases an aberrant obturator artery from the deep epigastric passes downwards by the edge of Gimbernat's ligament in such close proximity to the inner margin of the opening that it would be in danger of being cut in the operation for relief of a strangulated hernia. More frequently, however, when the aberrant vessel is present it passes downwards by the outer edge of the aperture of the crural canal.

The crural canal terminates opposite the upper part of the saphenous opening, and a hernial protrusion which has passed through the canal receives, therefore, no covering from the fascia lata. The coverings of a femoral hernia are—the peritoneum of the abdominal wall forming the *sac*, the remains of the septum crurale, the anterior wall of the sheath of the vessels, and the cribriform fascia which covers the saphenous opening.

The name, *deep crural arch*, is sometimes given to the arch formed by Gimbernat's ligament and the fascia transversalis over the crural canal and the vessels as they pass between the abdomen and the thigh.

The *deep abdominal ring—the inguinal canal—inguinal hernia.* At the lower part of the anterior abdominal wall, about half an inch above the middle of Poupart's ligament, the fascia transversalis is pierced by the spermatic cord in the male and the round ligament of the uterus in the female, and the opening thus formed in the fascia is called the *internal or deep abdominal ring.* From its margins a delicate continuation, the *infundibuliform* fascia, is prolonged onwards as an investment of the structures which pass through the ring. The upper and outer margins of the ring are somewhat weak, but the inner and lower margins are considerably strengthened by an intimate connection of the fascia transversalis with the outer edge of the conjoined tendon of the internal oblique and transversalis muscles. Close to the inner margin of the ring the deep epigastric artery passes upwards and inwards behind the inguinal canal in a sheath derived from the fascia transversalis.

The inguinal canal, about one and a half inches in length, is the

oblique passage between the deep and the superficial abdominal rings, and runs immediately above and almost parallel to the inner half of Poupart's ligament. It is lined by the infundibuliform fascia. Above, it is crossed in front by the lower border of the internal oblique muscle, continuous with which in front of the canal lie the fibres of the cremaster muscle, much better developed in the male than in the female. More superficially in front lies the tendon of the external oblique muscle. Behind the canal lies the conjoined tendon, closely adherent to which, on the deep surface, is the lower part of the fascia transversalis. The deep epigastric artery crosses behind the canal in close proximity to the inner edge of the deep ring.

An inguinal hernia may enter the canal by the deep ring, in which case its neck lies external to the deep epigastric artery, and it is called an *oblique or external hernia.* On the other hand, it may pass through the abdominal wall in the line of the canal at any spot between the artery

FIG. 298.—THE SUPERFICIAL ABDOMINAL RING. *a*, Fascia of Scarpa; *b*, intercolumnar fascia; *c*, spermatic cord.

FIG. 299.—THE CONJOINED TENDON. *a*, Internal oblique muscle (cut through and reflected); *b*, transversalis muscle; *c*, cremaster; *d*, testicle; *e*, tendon of external oblique (reflected); *f*, conjoined tendon; *g*, deep epigastric artery.

and the position of the superficial ring, and in this case receives the name of *internal or direct hernia.* Either form of hernia may remain inclosed within the wall, or may pass on through the superficial ring to the scrotum or labium. The ordinary contents of the canal usually lie behind the hernia in each case.

In both forms the protrusion receives a covering from the peritoneum of the anterior abdominal wall, which is called the *sac* of the hernia, in association with which there is usually a delicate layer of subperitoneal tissue. The coverings of an oblique inguinal hernia, retained within the abdominal wall, are, in addition to the sac, simply those which have already been enumerated as forming the immediate surroundings of the

inguinal canal, namely—the infundibuliform fascia surrounding the sac, muscular fibres of the internal oblique and cremaster, and the tendon of the external oblique in front; the conjoined tendon with the fascia transversalis lying behind. In the scrotum this form of hernia, in addition to the dartos tissue, is surrounded by the intercolumnar fascia from the margins of the superficial ring, the cremasteric fascia, into which the cremaster muscle is continued, and the infundibuliform fascia.

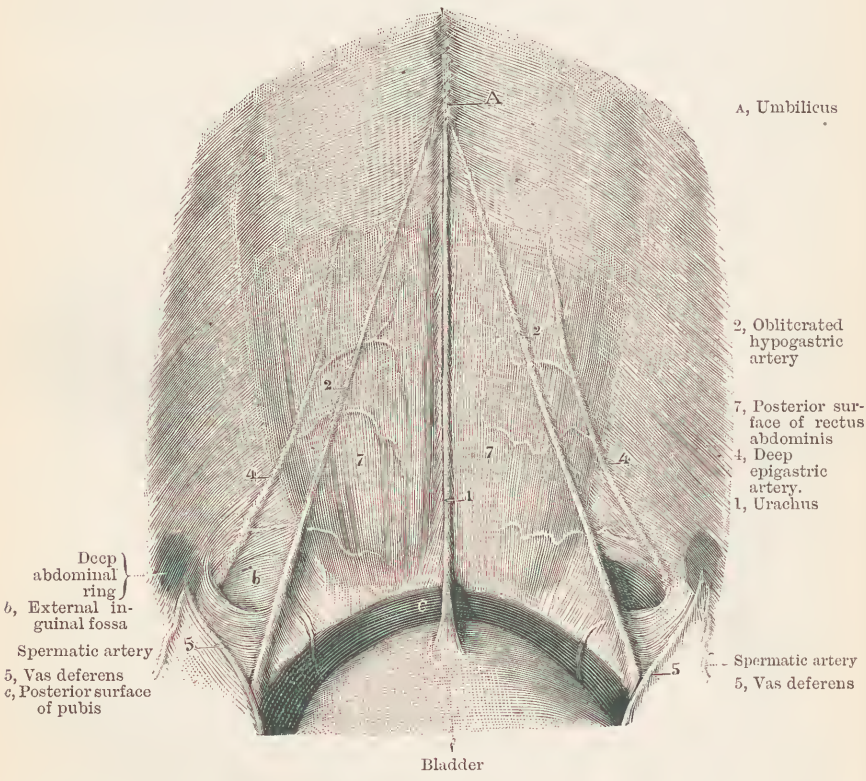


Fig. 300.—The Lower Part of the Anterior Abdominal Wall, seen from behind. (L. Testut.)

A direct hernia, in addition to the sac and the subperitoneal tissue, carries before it a portion of the fascia transversalis and conjoined tendon, usually associated as a single covering, and, if retained within the wall, lies behind the lower part of the external oblique tendon. In the scrotum its coverings are similar to those of the oblique form, with the exception that the investment from the fascia transversalis and conjoined tendon replaces the infundibuliform fascia.

When the anterior abdominal wall is viewed from the deep surface, the deep epigastric artery passing towards the outer margin of the rectus abdominis muscle makes with it the sides of a triangle of which the inner

part of Poupart's ligament is the base; this is called the *triangle of Hesselbach.* Within this triangle a direct hernia pierces the wall; external to it an oblique hernia enters the deep abdominal ring. A much more prominent fold of peritoneum, however, than that formed by the deep epigastric artery is caused by the obliterated hypogastric artery, which, passing from the side of the bladder to the umbilicus, crosses behind the inguinal canal a little internal to the deep epigastric artery. The depressions on either side of this prominent fold are sometimes called the *external and internal inguinal fossae.* These names are somewhat confusing, for while a hernia piercing the wall in the internal fossa is always of the direct or internal order, one piercing in the external fossa is direct or internal on the one hand or oblique or external on the other, according as it passes to the inner or to the outer side of the deep epigastric artery.

MUSCLES AND FASCIA OF THE PERINEUM.

In the posterior part of the perineum or pelvic outlet the anus is surrounded by the external sphincter muscle, so named to distinguish it from a somewhat deeper band of fibres, the internal sphincter, which, however, is to be regarded merely as a thickened portion of the proper musculature of the bowel. From the pelvic wall on either side the levator ani muscle sweeps downwards and inwards to blend with the wall of the lower part of the rectum, the terminal part of the bowel, and to form with its fellow a median raphe behind and, for a short distance, in front of the anal aperture. In the male the bladder and prostate gland lie immediately in front of the rectum, and are partially supported by the anterior portions of the levatores ani muscles, and the urethra passes through the prostate, and is directed forwards under the arch of the pubis to enter the penis. Upon the upper surface of the levatores ani muscles the recto-vesical fascia sweeps inwards and downwards from the pelvic wall to the bladder and rectum, and forms a complete floor of fascia to the pelvic cavity. The lower part of the obturator internus mnscle, beneath the line of reflection of the recto-vesical fascia, is lined by the obturator fascia, and the space on each side of the lower part of the rectum, between the obturator fascia and the under surface of the levator ani muscle, is named the *ischio-rectal fossa.* In the anterior part of the perineum, in front of the ischial tuberosities, a double layer of fascia, the triangular ligament of the urethra, stretches from side to side between the opposite margins of the ischio-pubic arch. The posterior or upper of the two layers is at its margins closely connected along the line of its bony attachment with the obturator fascia, and in its central part is blended on the under surface of the prostate with the recto-vesical fascia. In the male the triangular ligament is pierced by the membranous portion of the urethra, and between its layers lies the constrictor urethrae muscle. Upon the superficial aspect of the under or anterior layer of the ligament lies the

root of the penis formed of the bulb in the middle line, and the crura of the corpora cavernosa at the sides. The crura are covered by the erectores penis muscles, and the bulb by the accelerator urinae. In the female the vagina intervenes between the bladder and rectum, and passes through the triangular ligament; the accelerator urinae is represented by the sphincter vaginae and the erectores penis by the erectores clitoridis muscles.

The *central point of the perineum* in the male is a spot about an inch in front of the anal aperture; it marks the posterior extremity of the bulb. To this point the anterior extremity of the sphincter ani reaches, becoming confluent with the posterior part of the accelerator urinae, and the superficial transverse muscles from the ischial tuberosities join in the interlacement. In the female the corresponding muscles meet a point between the vaginal and anal orifices. A somewhat firm mass of the superficial connective tissue at the central point of the perineum is sometimes spoken of as the *perineal body.*

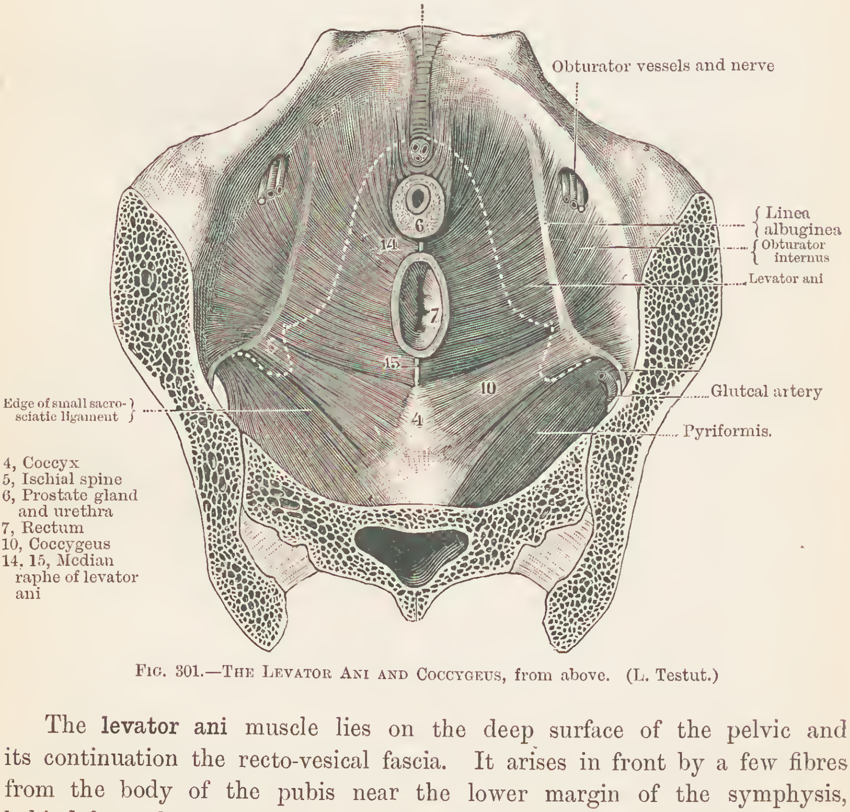


Fig. 301.—The Levator Ani and Coccygeus, from above. (L. Testut.)

The **levator ani** muscle lies on the deep surface of the pelvic and its continuation the recto-vesical fascia. It arises in front by a few fibres from the body of the pubis near the lower margin of the symphysis, behind from the margin of the ischial spine, and between these points from the pelvic fascia. The anterior fibres of the muscle pass backwards,

downwards, and inwards, embracing the neck and base of the bladder, and in the female the vagina, and meet the corresponding fibres from the opposite side in the middle line in front of the anus, and are connected there with the deeper fibres of the superficial sphincter; in the male the anterior fibres of the muscles embrace the sides of the prostate and meet below the gland. The fibres next in origin pass to the rectum and blend with its wall, which they enter between the deep and superficial sphincters. The posterior fibres, forming the greater part of the muscle, pass over the sides of the rectum, and are inserted into a median raphe prolonged backwards to the point of the coccyx. A few of the most posterior fibres are attached to the sides of the coccyx.

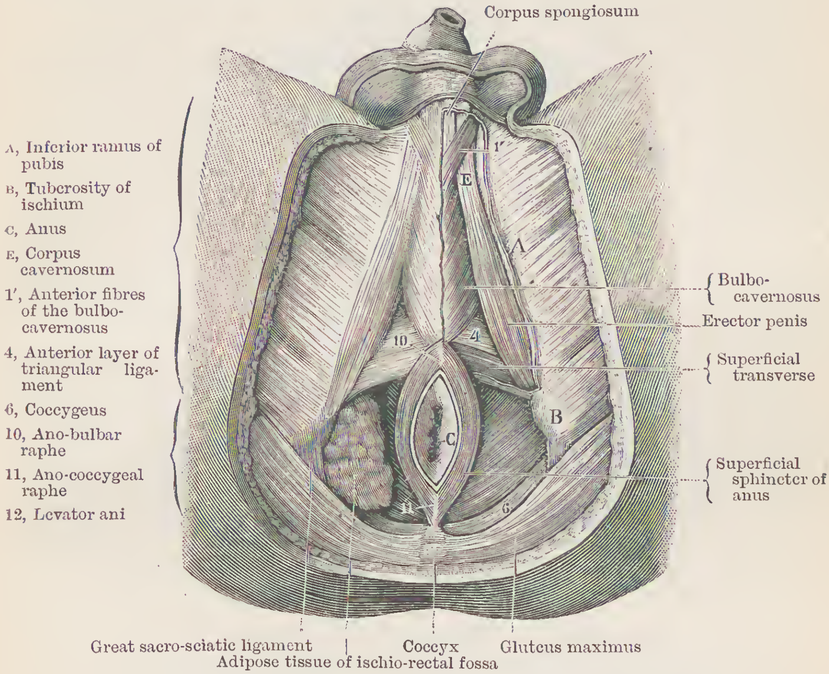


FIG. 302.—SUPERFICIAL PERINEAL MUSCLES OF THE MALE. (L. Testut.)

The **coccygeus**, triangular in outline, is continuous with the posterior edge of the levator ani. Narrow at the origin it springs from the spine of the ischium. Broad at its insertion it is attached chiefly to the side of the coccyx and partly also to the side of the sacrum.

The **sphincter ani externus**, or **superficial sphincter** muscle, three-quarters of an inch to an inch in depth, surrounds the lower part of the rectum and encircles the anal aperture. Posteriorly the fibres are continued backwards along the ano-coccygeal raphe to the point of the coccyx; anteriorly they pass forwards to the central point of the perineum, where they are connected with the bulbo-cavernosus or sphincter vaginae muscle, according

to the sex. Many are inserted into the skin. The fibres of the levator ani which enter the rectal wall become intimately associated with those of the external sphincter.

The **superficial transverse** muscle is a small muscular slip, very variable in size, and sometimes absent altogether, arising from the inner surface of the ischial tuberosity, and inserted into the central point of the perineum, where it is connected with the superficial sphincter ani and with the bulbo-cavernosus, or in the female sphincter vaginae.

The **bulbo-cavernosus, ejaculator** or **accelerator urinae** muscle, of the male, invests the bulb and the posterior part of the corpus spongiosum.

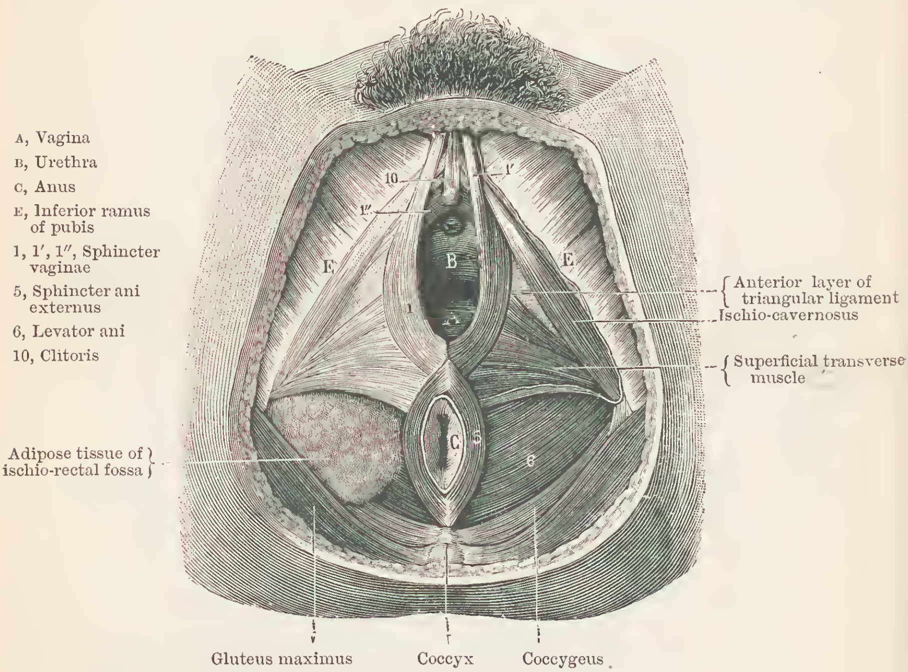


Fig. 303.—Muscles of the Perineum in the Female. (L. Testut.)

A median tendinous raphe belonging to the muscle and dividing it into lateral portions is continued from the central point of the perineum forwards on the under surface of the bulb, and from it the fibres spring, the posterior being connected behind with the sphincter ani externus. The fibres of each side diverge from one another. The posterior, which embrace the bulb, are inserted into the under surface of the triangular ligament; the anterior, which embrace the hinder part of the corpus spongiosum, pass to a tendinous expansion on the upper or dorsal surface of that body. At the extreme anterior border of the muscle a few fibres are directed forwards on each side to the crus penis, which they join in front of the ischio-cavernosus muscle.

The **sphincter vaginae** muscle of the female corresponds to the bulbo-cavernosus of the male. It is attached behind to the central point of the perineum, where it is continuous with the sphincter ani externus. Its fibres pass forwards, surrounding the vaginal orifice, and covering the outer surfaces of the bulbi vestibuli. They are attached in front partly to the vestibular wall, and partly to the corpora cavernosa clitoridis.

The **ischio-cavernosus** muscle in the male, or **erector penis**, invests the crus penis. Its fibres arise from the inner surface of the tuberosity and ramus of the ischium behind and on both sides of the crus, and converge to a tendinous expansion which passes forwards on the under surface of the crus, and gradually unites with its wall.

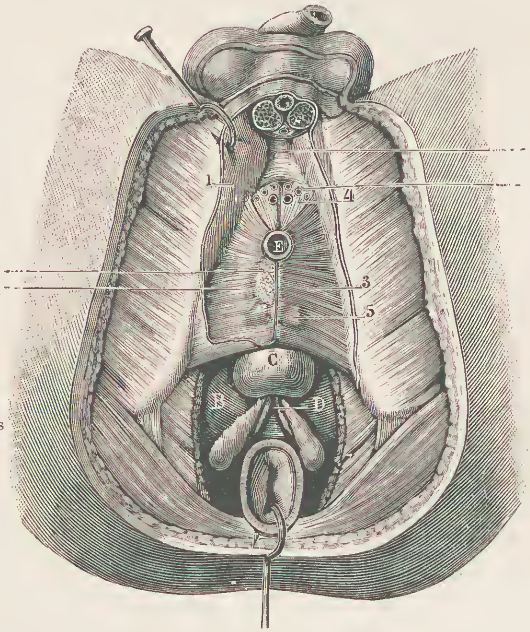


FIG. 304.—DEEP PERINEAL MUSCLES OF THE MALE. The anterior layer of the triangular ligament of the left side has been reflected; the lower and hinder portions of the levatores ani and the recto-vesical fascia have been removed; the anus has been drawn backwards. (L. Testut.)

The **ischio-cavernosus** or **erector clitoridis** of the female is similar in arrangement to but smaller in size than the erector penis.

The **constrictor** or **compressor urethrae** muscle of the male, or *muscle of Guthrie*, is constituted by a set of fibres lying between the layers of the triangular ligament. The greater number pass across the middle line between the inferior pubic and ischial rami of opposite sides, some in front of and some behind the urethra, and associated with these are some circular fibres surrounding the canal. The most posterior fibres have a direction slightly backwards towards the central point of the perineum and are sometimes separately described under the name of *deep transverse muscle*.

A set of fibres passing obliquely backwards from the fore part of the subpubic arch on each side to the urethra and anterior part of the prostate has been described as the *muscle of Wilson*; its presence is denied by many anatomists.

The **constrictor urethrae**, or **deep transverse** muscle, of the female consists of fibres partly transverse and partly oblique in direction, arising from the inferior pubic and ischial rami on each side, and passing inwards between the layers of the triangular ligament to blend with the vaginal wall and surround the urethra.

Nerves. All the muscles of the perineum, with the exception of the coccygeus, are supplied by the pudic nerve. The coccygeus receives its supply from the coccygeal plexus; the fourth sacral nerve sends an additional branch to the levator ani.

Actions. The sphincter ani firmly closes the anal aperture. The fibres of the levatores ani which are attached to the wall of the bowel raise the lower part of the rectum and oppose the action of the sphincter; those fibres which pass across the side of the bowel to the ano-coccygeal raphe raise and compress the lower part of the rectum, and assist in the evacuation of its contents. The erectores penis, by compressing the crura, bring about erection of the penis. The bulbo-cavernosus and constrictor urethrae compress the urethral canal, and assist in expelling its contents.

FASCIA OF THE PERINEUM AND PELVIS.

The *superficial fascia* of the posterior part of the perineum sinks very deeply into the ischio-rectal fossa, and is heavily loaded with fat. In the anterior part of the perineum the deeper layer of the superficial fascia is known as *Colles' fascia.* In front it is continuous with the dartos; at the sides it is bound down to the margins of the ischio-pubic arch extending as far backwards as the ischial tuberosity; behind it bends deeply round the superficial transverse muscle and joins the posterior edge of the triangular ligament. Between it and the triangular ligament lie the crura and bulb; the superficial perineal vessels and nerves pierce it in their passage forwards to the scrotum. An incomplete vertical septum in the middle line separates the space into lateral portions. From the attachments of the fascia it follows that fluid effused between it and the anterior layer of the triangular ligament cannot pass backwards to the posterior part of the perineal space or outwards into the thighs, but may pass forwards to the anterior abdominal wall.

The **pelvic fascia** is continued downwards from the abdominal walls, and is therefore continuous with the iliac and transversalis fascia. It is attached firmly to the ilio-pectineal line. In the posterior part of the pelvis it forms a thin layer which covers the pyriformis muscle and the nerves of the sacral plexus, and is pierced by the branches of the internal iliac vessels which pass through the great sacro-sciatic notch. In front of

the notch it lines the upper part of the obturator internus only, and, along a line drawn from the spine of the ischium to the symphysis, near its lower margin, it leaves the muscle and sweeps downwards and inwards to the middle line of the pelvic outlet, and there the layers of opposite sides meeting form for the pelvic cavity a floor of fascia which supports and forms a sheath for the bladder, and in the male the prostate gland, and is pierced by the rectum, and in the female by the vagina also. The portion of the fascia which sweeps inwards from the wall, and which, as above described, is continuous with the pelvic fascia, is, from its connection with the viscera, specially named the *recto-vesical fascia*. The lower part of the obturator internus is covered by a layer which is named the *obturator fascia*, and the under surface of the levator ani is clothed by the *anal fascia;* these layers line the walls of the ischio-rectal fossa, and are continuous with one another at the apex of that space.

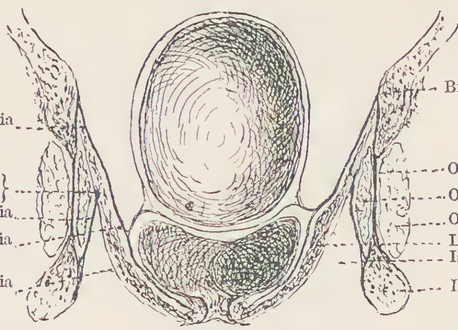


FIG. 305.—DIAGRAMMATIC SECTION THROUGH BLADDER, RECTUM, AND ANUS, to show the relations of the pelvic fascia.

The levator ani muscle lies close on the deep surface of the recto-vesical fascia; its anterior portion springs from the pelvic surface of the pubic bone, but in the greater part of its extent it arises from the deep surface of the pelvic fascia. Most of its fibres take origin along a specially strengthened line, the *white line*, or *linea albuginea*, which marks the place where the pelvic fascia leaves the surface of the obturator internus, and is continued into the recto-vesical fascia; a few, however, spring from the fascia above the level of the white line. The obturator fascia reaches up to the white line, and becomes there continuous with the anal fascia. At the upper margin of the obturator foramen the pelvic fascia is pierced by the obturator vessels and nerve.

The *recto-vesical fascia* sweeps backwards from the anterior, and inwards from the lateral walls of the pelvis to the bladder, which it reaches near the base and immediately splits into two layers. One passes upwards over the bladder, blending with its wall and forming its sheath; the other passes downwards sheathing the base and, in the male, inclosing the prostate. The attachments to the bladder constitute the *true ligaments* of that organ. The *anterior true ligament* on

each side is a strong band of fibres, with which some involuntary muscular fibres are mixed, passing from the body of the pubis to the anterior part of the base of the bladder; the *lateral true ligament*, sweeping from the wall along the line of reflection, is continued backwards from the anterior, than which it is, however, much weaker in structure. Between the anterior ligaments of opposite sides the fascia is thin, and, viewed from above, depressed into a hollow. The portion of fascia which passes downwards under the base of the bladder in the male surrounds very closely the prostate gland, forming a sheath for it, and gives off a layer which incloses the vesiculae seminales. The sheath of the prostate is very strong, and is mainly derived from the fibres of the under surface of the anterior true vesical ligaments. In front the weak fibres, passing back to the prostate from

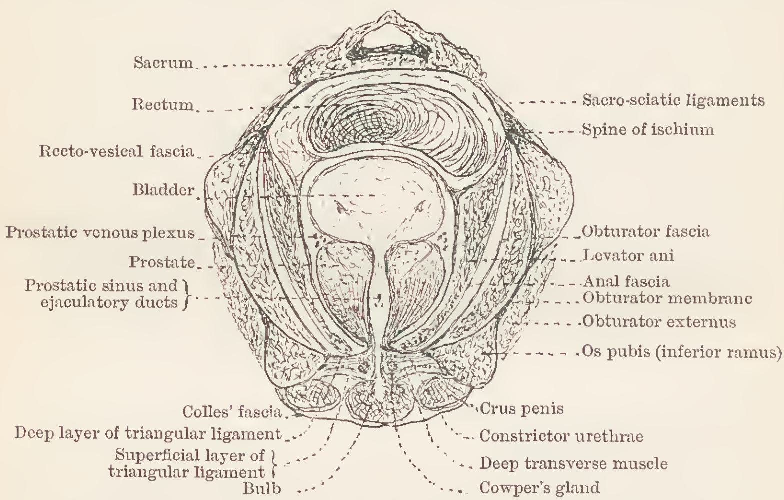


FIG. 306.—DIAGRAM OF SECTION OF PELVIS, dividing longitudinally the prostatic portion of the urethra.

the symphysis, are pierced by the dorsal vein of the penis, which enters a plexus of veins lying between the proper capsule of the gland and its sheath from the recto-vesical fascia; the veins lie at the base and the lower part of the sides of the organ, but over the rest of the area the sheath and the capsule are closely adherent. Behind the bladder, between it and the rectum, the layers of recto-vesical fascia of opposite sides in the male subject meet in the middle line, but in the female they pass on to the vaginal wall. Further back, on the side of the rectum, the fascia splits, about three inches from the anus, one portion passing upwards and the other downwards, both blending with the coats of the bowel. The attachment to the rectum is sometimes named *ligament of the rectum.*

The *obturator fascia* is attached below to the bone along the lower margin of the obturator internus muscle; behind, it is attached to the great and

small sacro-sciatic ligaments; above, it reaches to the white line, where it becomes continuous with the anal fascia. It lines the outer wall of the ischio-rectal fossa, and in a special canal in its substance the pudic vessels and nerves run forwards in a portion of their course.

The *anal fascia* is a delicate layer which covers the under surface of the levator ani, and lines the inner wall of the ischio-rectal fossa.

The **subpubic fascia or triangular ligament of the urethra.** Two layers of fascia, constituting together the triangular ligament of the urethra, stretch from side to side in the anterior part of the perineum. They are pierced by the membranous part of the urethra in the male, and by the urethra and vagina in the female, and between the two lie the constrictor urethrae muscle, the pudic vessels and nerves in a portion of their course, and Cowper's or Bartholin's gland, according to the sex.

The *anterior* or *under layer of the triangular ligament*, moderately strong, is attached in front to the subpubic ligament, and at the sides to the inner lips of the rami, extending as far back as the tuberosity. At its posterior edge it is united with the posterior layer of the ligament, and with Colles' fascia, which to join it turns round the superficial transverse muscle. In the male it is pierced in the middle line, about an inch from the symphysis, by the urethra, which almost immediately after enters the penis. The posterior part of the spongy body terminating in the bulb, and the crura of the penis, lie upon its anterior surface. The vessels of the corpora cavernosa and those of the bulb pass through it as do also, close to the symphysis, the dorsal vessels and nerves of the penis.

The *posterior* or *upper layer of the triangular ligament* lies upon the upper surface of the constrictor urethrae muscle, and separates it from the anterior part of the levator ani. Traced from either side it passes inwards from the inner margin of the ramus, where, at its attachment to the bone, it is continuous with the anterior part of the obturator fascia. In the male it reaches the middle line at the base of the prostate, and is there continuous with the recto-vesical fascia which forms the sheath of the gland. The urethra as it is leaving the prostate passes through it. At its posterior border it is blended with the anterior layer of the ligament, and is pierced by the pudic vessels and nerves as they pass forwards. In the female the lateral portions traced inwards reach the vaginal wall where they blend with the recto-vesical fascia.

The *ischio-rectal fossa.* At the posterior part of the perineum there lies on each side, between the wall of the bowel and the tuberosity of the ischium, a considerable space named the *ischio-rectal fossa*, which is filled with fat and traversed by branches of the pudic vessels and nerves. In cross section the space is triangular in outline, having the skin and fascia stretching between the anal opening and the tuberosity as its base. The outer wall is formed by the obturator fascia clothing the lower part of the obturator internus muscle, the inner wall by the levator ani

muscle covered by the anal fascia. The apex is above at the white line. In front, the space, much narrowed, extends forwards almost to the symphysis on the upper or posterior surface of the triangular ligament.

Surgical anatomy of the pelvic fascia. The relations of the fascia to the viscera are of considerable surgical importance. Rupture of the male urethra, with subsequent extravasation of urine, takes place most frequently in front of the anterior layer of the triangular ligament, and the attachment of Colles' fascia to the posterior edge of the triangular ligament and to the rami prevents the extravasated fluid from reaching the posterior part of the perineal space or the thighs; but, on the other hand, directs it forwards to the abdominal wall, where it ascends under Scarpa's fascia. Less common is the rupture of the urethra between the layers of the triangular ligament, and when it happens the fascia for a considerable time resists the passage of the extravasated fluid. The recto-vesical fascia, forming the anterior and lateral true ligaments of the bladder, reaches that organ at the upper margin of the base, consequently the whole base of the bladder, with the vesiculae seminales and the prostate gland, is excluded from the pelvic cavity and projects into the perineum. The prostate, however, receives an exceedingly strong sheath from the downward continuation of the fascia. Between the base of the bladder and the prostate on the one hand, and the anterior wall of the lower part of the rectum on the other, a comparatively thin septum of fascia intervenes. The base of the bladder immediately above the prostate may be punctured from the rectum without opening the pelvic cavity. Prostatic abscesses open usually into the urethra, but extravasation of urine or pus has in rare cases taken place into the cavity round about the base of the bladder, and in such cases the extravasated fluid may pass downwards upon the rectum. The portion of the fascia which passes to the side of the rectum is weaker than that which is attached to the bladder; it reaches the side of the bowel about three inches from the lower end. A portion of the fascia, with the levator ani on its deep surface, is prolonged downwards on the lower part of the bowel, strengthening its wall. The rectal opening of a fistula in ano is rarely found higher up than an inch from the margin of the anus, and in the majority of cases is placed even lower than that.

DEVELOPMENT AND MORPHOLOGY OF THE VOLUNTARY MUSCLES.

The voluntary muscles of the trunk are derived from the muscle plates formed from the outer regions of the mesoblastic somites. Some of the muscles of the head are derived from the lateral mesoblast, others from dorsally placed masses of mesoblast which correspond to the somites of the trunk. The muscles of the limbs appear in the higher forms to arise

independently of the muscle plates from the mesoblastic tissue of the limb outgrowths; but in the lower forms, for instance in elasmobranch fishes, the limb muscles are formed, to a large extent at least, from processes which are budded from the muscle plates of the segments to which, in each case, the limb corresponds.

The mesoblastic somites present at an early date a central cavity which, in certain cases, as for instance in those of the anterior somites of the embryo duck, can be seen to be continuous for a short time with the general body cavity. The outer and inner walls of the somites are at first of equal thickness, but at an early stage the inner wall undergoes a rapid growth, with the result that in each case the originally centrally-placed cavity comes to occupy a lateral position. The greater part of the thickened inner wall, formed of irregular or stellate cells, gives rise to the tissue out of which the vertebral column is formed; the remainder of each somite presenting in its interior the original cavity forms a muscle plate. The outer wall of the muscle plate is formed of elongated columnar cells, the inner wall of two or three layers of flattened cells. The muscle plates grow rapidly, extending ventrally into the somatopleure and dorsally towards the vertebral column, the growth taking place at the dorsal and ventral angles of the plates where the outer walls become continuous with the inner walls. The cells of the inner walls of the muscle plates give rise to a system of muscular fibres; the changes which take place in those of the outer walls have not been clearly followed.

The original muscular fibres have at first a longitudinal direction, and those of the successive segments are separated from one another by intersegmental septa along which the nerves run, and in which, in the thoracic region, the ribs are formed. Subsequently, by the complete or partial obliteration of the septa, and by the growth and the increase in numbers of the fibres, there is formed a complicated system of muscles, the individual members of which are separated from one another and collected into groups by new connective-tissue septa derived from the mesenchyme.

The fascia which surrounds the muscles forms a general superficial investment and four great septa. One of the septa, dorsal in position, extends from the spines of the vertebrae to the surface and separates the dorsal muscles of opposite sides from one another; it is represented in the adult by the ligamentum nuchae and by the interspinous and supraspinous ligaments. Another, the haemal septum, passes ventralwards; it is present in the caudal region of lower forms, but in the rest of the trunk it is split into lateral portions between which the visceral cavity is interposed; it is represented by the lining fascia of the visceral cavity. The two others, one on each side of the body, lateral in position, divide the musculature of each lateral half into a dorsal and a ventro-lateral portion; the remains of these septa persist as the middle layers of the lumbar aponeurosis. Each of the two great groups of muscles is further

subdivided, and in the planes of division the main branches of the nerves run.

The dorsal group of muscles is supplied by the posterior primary divisions of the nerves; the fibres which compose it are chiefly longitudinal in direction and many of the more deeply placed are confined to one segment. It is divided by a longitudinal partition into an outer and an inner portion; to the outer portion belong the splenius and erector spinae muscles; to the inner portion, on the other hand, the complexus, semispinalis, multifidus spinae, the median lumbar intertransverse, the interspinales, and the posterior short cranio-vertebral muscles.

The ventro-lateral group is supplied by the anterior primary divisions of the nerves; it is more complicated than the dorsal group and presents a greater modification from the original segmental type; many of its fibres have an oblique or transverse direction. It is subdivided into two layers between which the nerves course in the body wall, and the more superficial of the two is again subdivided into different strata. The deeper of the two main layers forms three sets of muscles which may, from their relative positions, be termed (*a*) hyposkeletal, (*b*) lateral, and (*c*) ventral. The hyposkeletal muscles are regarded by some observers as arising independently of the muscle plates from the general mesoblast, but it is probable that they are formed, as indicated above, from the deeper layer of the lateral musculature; they lie upon the under or, from the point of view of human anatomy, anterior surface of the vertebral column, and are represented in man by the rectus capitis anticus major, the longus colli, and probably by the vertebral portion of the diaphragm. The lateral muscles of the deeper layer are the transversalis abdominis, and probably also the coccygeus, levator ani, deep transversus perinei, internal intercostals, scalenus anticus, and anterior cervical intertransverse muscles. The ventral muscles are represented by the rectus abdominis, triangularis sterni, omo-hyoid, sterno-thyroid, and sterno-hyoid muscles.

The more superficial layer of the lateral group is represented in the thorax, abdomen, and pelvis by the external intercostals, the levatores costarum, the internal and external oblique muscles of the abdomen, the quadratus lumborum, the lateral lumbar intertransverse, and the superficial perinaeal muscles, and in the neck by the posterior and middle scaleni, and by the posterior intertransverse muscles. As more superficial strata belonging to this layer there may be reckoned the three serrati muscles, the rhomboidei, the latissimus dorsi, the levator anguli scapulae, the pectoralis major and minor, and probably portions at least of the sterno-mastoid and trapezius.

The muscles of the head. In the region of the head the mesoblast extends forwards on each side as a lateral plate; mesoblastic somites are not formed, but the formation of the successive branchial arches affords evidence of a segmentation. In the lower forms, for instance in elasmobranch fishes, each lateral plate of head mesoblast is cleft into a somatic

and splanchnic layer which form the walls of a cavity continuous behind with the body cavity; on the formation of the branchial arches this cavity is broken up into a number of segments, the first of which is premandibular, the second occupies the mandibular, the third the hyoid arch, while the others correspond to the succeeding branchial arches. Each of the first three sections of the head cavity is formed of a dilated dorsal portion and a narrow ventral portion. The dorsal portions are regarded as corresponding to the mesoblastic somites in the trunk; from their walls the muscles of the orbit are formed. From the inner or splanchnic walls of the narrow ventral portions contained within the mandibular, hyoid, and the succeeding arches, the mandibular, hyoid, and branchial muscles are developed. Among higher forms, in reptiles and birds, traces of the formation of a head cavity and its division into successive segments have been observed. A number of segments have been counted, the dorsal portions of which, corresponding to somites, are said to be formed in order from behind forwards. The most anterior head-somite gives origin to the muscles of the orbit supplied by the third nerve; the second to the superior oblique muscle, supplied by the fourth nerve; the third to the external rectus muscle, supplied by the sixth nerve; behind this two or three somites seem to disappear entirely; from the hinder head-somites, according to some observers, the muscles which pass from the head to the shoulder-girdle are developed. From the walls of the ventral or visceral portion of the section of the head cavity belonging to the mandibular arch there are developed the muscles of the jaws and the tensor palati, supplied by the motor branch of the fifth nerve; and from the corresponding regions of the hyoid arch there arise the stapedius and the muscles connected with the hyoid bone, supplied by the facial nerve; the superficial muscles of the face and neck supplied by the seventh nerve have probably spread from the region of the hyoid arch. In the splanchnic wall of the pharynx corresponding in position to the first branchial arch there are developed the pharyngeal muscles supplied by the glosso-pharyngeal and its associated nerves, and with these, judging from its nerve supply, the levator palati must probably be reckoned, although its position immediately behind the Eustachian tube would seem to warrant the supposition that it was developed from the hyoid arch. The intrinsic muscles of the tongue and those supplied by the true hypoglossal branches probably also spring from the splanchnic mesoblast in the neighbourhood of the ventral extremities of the anterior branchial arches.

THE VASCULAR SYSTEM.

THE HEART.

The heart is a hollow organ with muscular walls. The blood enters it through six large channels and one smaller one,—the four pulmonary veins from the lungs, the superior vena cava and the inferior vena cava from the body generally, and the coronary sinus from the walls of the heart itself. It distributes the blood through the aorta and the pulmonary artery. It is inclosed in a membranous sac, the pericardium, which also completely or partially invests for a little distance the great vessels connected with it.

It has the shape of a somewhat flattened cone, with anterior and posterior surfaces and right and left borders. Its base lies on the vertebral column in the region corresponding to the bodies of the sixth, seventh, and eighth dorsal vertebrae, the structures in the posterior mediastinum intervening; the apex projects downwards, forwards, and to the left, and is found opposite a spot in the fifth left intercostal space three and a half inches from the middle line of the sternum. The anterior surface looks upwards as well as forwards, the posterior downwards and backwards.

It is divided by a longitudinal septum into right and left portions, each of which is again subdivided by a transverse constriction into two chambers, auricle and ventricle, the former being superior and dorsal in position, the latter inferior and ventral. A deeply marked groove, the *auriculo-*

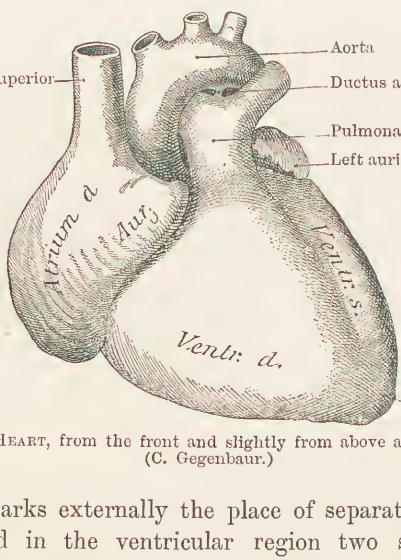


FIG. 307.—THE HEART, from the front and slightly from above and from the right. (C. Gegenbaur.)

ventricular sulcus, marks externally the place of separation between auricles and ventricles, and in the ventricular region two shallow longitudinal depressions anterior and posterior in position, the *interventricular grooves*, mark on the surface the line of division between the ventricles. The septum,

which separates the right and left divisions of the heart from one another, is so placed that the right division occupies the greater part of the anterior surface, the left division the greater part of the posterior surface of the organ. The anterior and posterior interventricular furrows meet one another a little to the right of the apex, which is formed from the left ventricle only. Of the borders of the heart, the right, or *margo acutus*, is narrower and longer than the left, or *margo obtusus*.

The **auricular portion of the heart** has the form of an irregularly-shaped crescent, embracing from behind and from the right side the base of the aorta, and having its horns or extremities prolonged, as the *auricular appendices*, towards the sides of the pulmonary artery. The auricular portion rests behind on the column, the pericardium and the structures in the posterior mediastinum intervening. The septum is directed from behind forwards and to the left, so that the right auricle, which lies

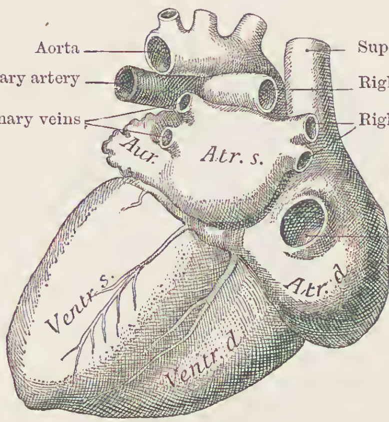


Fig. 308.—The Heart, from behind. The coronary sinus is seen in the auriculo-ventricular furrow; the left coronary vein with a posterior cardiac tributary and the posterior interventricular vein are also shown. (C. Gegenbaur.)

to the right side of and in front of the aorta, is narrow behind, and broad and expanded in front, while the left is somewhat flattened out behind the aorta and pulmonary artery.

The **right auricle**, viewed from the front and the outer side, presents a broad, prominent, somewhat four-sided surface, prolonged anteriorly into the appendix, which projects towards the left. The superior and inferior venae cavae enter respectively at the upper and lower posterior angles. When the auricle is opened, the inner and posterior parts of its wall are found to be smooth, but the anterior part and the wall of the appendix are made rough by the presence of vertical muscular bands, standing out as strong ridges, the *musculi pectinati*, under the endocardial lining. The posterior limit of the roughened area is marked on the external surface by a groove which runs from in front of the entrance of the vena cava superior to the right of the opening of the inferior cava, and which has received

the name of *sulcus terminalis*. On the right surface of the interauricular septum is situated an oval depression, the *fossa ovalis*, which is bounded, except at its lower part, by a prominent margin, the *annulus ovalis*. The fossa ovalis is the remains of what was, in foetal life, the *foramen ovale*, an open passage between the auricles, which afterwards became closed by the application of a valvular fold. The communication between the auricles sometimes persists in the adult as a narrow oblique passage. In front of the opening of the inferior vena cava, a fold of endocardium passes across the posterior part of the auricle to the lower extremity of the annulus ovalis; it is of very variable size, and frequently shows numerous small perforations. It is the remains of the *Eustachian valve*, a fold which, in foetal life, directed the blood of the inferior vena cava through the foramen ovale to the left auricle. There is no valve at the opening of the superior vena cava. Between the Eustachian valve and the auriculo-ventricular opening, which occupies the floor of the auricle, is the orifice

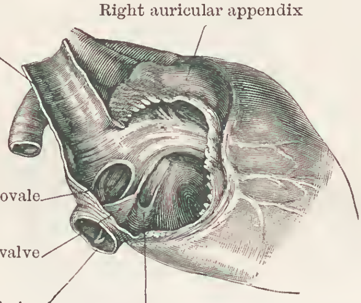


FIG. 309.—RIGHT AURICLE OF CHILD AT BIRTH, showing the foramen ovale. The anterior wall has been removed. (C. Gegenbaur.)

of the *coronary sinus*, into which the veins of the heart pour their blood. It is guarded by a thin imperfect valvular fold, the *valve of Thebesius*. Numerous small pits open upon the wall of the auricle; many of them are blind, but some contain the openings of small veins from the wall of the heart; they are known collectively as the *foramina of Thebesius*.

The **left auricle**, four-sided and somewhat flattened, is, to a large extent, hidden behind the aorta and pulmonary artery. Its appendix, which is the most superficial part, projects forward by the left side of the pulmonary artery. Internally it presents a smooth surface, except in the appendix, the walls of which are marked by prominent muscular ridges. Posteriorly the four pulmonary veins, two upon each side, open into it, the orifices being destitute of valves. On the septum the position of the foetal foramen ovale is marked by an irregularity of the surface, the most constant feature of which is a small depression with a slender limiting ridge below it, at the upper border of the original foramen. The auriculo-ventricular aperture lies in the anterior part of the floor.

The ventricular portion of the heart. Each of the two chambers into which it is divided presents two basally placed orifices, the auriculo-ventricular and the arterial, both of which are guarded by valves. The *auriculo-ventricular valve*, in each case, is formed of fibrous cusps or segments, pointed and free at their extremities, which project into the cavity, and confluent at their bases, where they form an annular membrane attached to the margin of the opening. The *arterial valve*, in each case, is made up of three semicircular segments (*semilunar or sigmoid*) formed of fibrous tissue, and attached by their convex borders to the wall of the artery at the place where it springs from the ventricle, while their free borders, which are nearly straight, project into the cavity. The free border of each segment is strengthened by a delicate fibrous band, and immediately below the middle of the margin there is a small thickening, the *nodulus* or *corpus Arantii*; the thinnest portions of each segment lie immediately below the lateral portions of the free border, and are named the *lunulae*. Opposite each segment there is a pouch or sinus of the wall of the vessel, which completes, with the corresponding segment of the valve, the wall of a cup; the pouches are termed the *sinuses of Valsalva*. When the ventricles are contracting and the blood is passing through the arterial orifices, the segments are applied to the walls of the sinuses; during the ventricular diastole regurgitation of blood from the arteries is prevented by the closure of the valves, the nodules coming into contact, and the lunulae of neighbouring segments overlapping.

The ventricular wall attains its maximum diameter, except in the case of the septum, about the junction of the basal and middle thirds. The wall of the left ventricle is two or three times thicker than that of the right. The *septum*, in its greater part, has almost the same diameter as the wall of the left ventricle, but is thickest in the region of the apex. It is somewhat curved, its right side being convex, while its left is concave, and, as a result, the outline of the right ventricle, in section, is crescentic, while that of the left is oval or circular. At its upper or basal portion the septum is in line, dorsally, with the inter-auricular septum, and intervenes between the auriculo-ventricular openings; further forwards it separates the right auriculo-ventricular from the aortic orifice; and still more ventrally, it passes between the posterior margin of the pulmonary and the anterior margin of the aortic orifice. As the septal cusp of the right auriculo-ventricular opening is placed a little lower than the anterior cusp of the left orifice, the septum intervenes for a short distance near its posterior part between the right auricle and the left ventricle. Immediately in front of the area last described, and close to the hinder margin of the right segment of the aortic valve, there is a small portion of the septum, the *pars membranacea*, which is very thin, and contains no muscular fibres; in abnormal circumstances it is occasionally deficient, permitting a communication between the ventricles.

The inner surface of the ventricular wall presents, in its greater part,

a complex arrangement of muscular elevations, which project into the cavities, and are termed *columnae carneae.* Some of these are simply projecting muscular ridges; others are attached to the wall at their extremities, and are free in their intermediate portions; others again, specially named the *musculi papillares*, are definitely arranged muscular projections attached basally to the wall in the region of the apex, and giving origin at their free extremities to a number of delicate tendons, the *chordae tendineae*, which pass to the margins and ventricular surfaces of the segments of the auriculo-ventricular valves. During the ventricular systole, the musculi papillares contract along with the walls of the ventricles, and the tightened chordae tendineae prevent the retroflexion into the auricles of the segments of the valves, which, applied to one another, and thus maintained in position, close the orifices.

The **right ventricle** occupies the greater part of the anterior surface and right border of the heart, and only a small portion of the posterior surface. Behind and below it rests upon the diaphragm, the central tendon of which is united with the fibrous layer of the pericardium. Viewed from the front it presents a triangular surface prolonged at the upper angle, the *conus arteriosus* or *infundibulum*, into the pulmonary artery. Except in the region of the infundibulum the inner surface of the wall presents a close reticulation of columnae carneae. The musculi papillares form two groups, respectively anterior and posterior in position. A fleshy band which is frequently found stretching across the cavity of the ventricle, from the septum downwards to the base of the anterior papillary muscles, is named the *moderator band.* The auriculo-ventricular orifice is placed a little below and to the right of that of the pulmonary

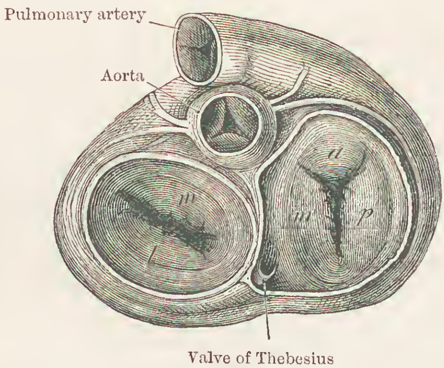


FIG. 310.—THE AURICULO-VENTRICULAR AND ARTERIAL VALVES, seen from above and behind after section through the auricles and arteries. (C. Gegenbaur.)

artery. The auriculo-ventricular orifice admits three fingers placed side by side. The valve which guards it, the *tricuspid valve*, is formed of three cusps, of which two are lateral and one is mesial in position; they may be named the anterior and posterior lateral, and the septal. From the anterior papillary muscles chordae tendineae pass to the angle between the two

lateral cusps; from the posterior muscles they are directed to the angle between the septal and posterior cusps; to the angle between the septal and anterior cusps there pass tendinous bands which spring from the septum either directly or by small muscular points. Sometimes one or other of the cusps is partially divided into two, and there are to be found in some cases small, intermediate cusps in the angles between the larger ones. The valve at the root of the pulmonary artery is not so strong as that at the base of the aorta.

The **left ventricle**, which rests below and behind on the diaphragm, occupies the greater part of the posterior surface of the ventricular portion of the heart, only a comparatively small portion of it appearing in front. It forms the whole apex. In the interior of the ventricle the columnae carneae present a complicated arrangement, especially at the apex. They are absent from the upper part of the septum and anterior wall, so that

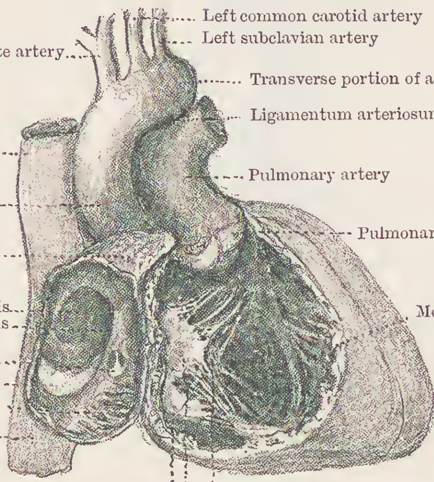


FIG. 311.—THE HEART, from before and the right side. The cavities of the right auricle and ventricle have been exposed by the removal of a portion of the wall.

the region of the cavity which is immediately below the aortic orifice, and has been named the *aortic vestibule*, presents a smooth surface. The musculi papillares form two large groups, one left or anterior in position, the other right or posterior. The orifices of the ventricle are situated very close together in the upper part of the ventricle, the aortic being higher than the other, and to the right of it. The auriculo-ventricular orifice, admitting only two fingers in normal circumstances, is smaller than that of the right side, and the valve which guards it, though similar in general construction to the tricuspid valve, is much stronger. It presents two cusps only, and has been named, in consequence, the *bicuspid* or *mitral valve*. The cusps are placed obliquely, and are of unequal size, the larger being anterior to the other, and to the right of it. The ventricular surface of

this cusp forms a portion of the aortic vestibule, and its base separates the aortic and auriculo-ventricular orifices from one another. The chordae tendineae are numerous and strong, and pass, like those of the right side, to the angles between the valves, and are attached to the free margins and ventricular surfaces. Occasionally small subsidiary cusps are found in the angles between the larger ones. The aortic orifice, circular in outline, is somewhat smaller than that of the pulmonary artery; the segments of its valve are much stronger than those of the right side. The sinuses of Valsalva are relatively to one another, right, left, and posterior in position; from the right and left the corresponding coronary arteries of the heart spring.

Position of the heart with reference to the chest wall. The base of the heart lies opposite the bodies of the sixth, seventh, and eighth dorsal vertebrae. The apex approaches the surface at a spot, in the fifth left inter-

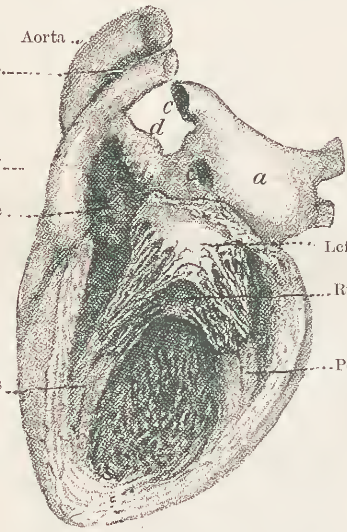


FIG. 312.—THE HEART, from behind and the left side after removal of the outer wall of the left ventricle.

costal space, three and a half inches from the middle line, and one and a half inches below the nipple. The area occupied by the heart may be marked out on the surface by three lines: (1) on the right side, a curved line with the convexity to the right, and reaching at the farthest about an inch and a half from the middle line, drawn from the sternal end of the third right costal cartilage to that of the seventh right costal cartilage; (2) a line drawn across, from the sternal end of the seventh right costal cartilage to the apex; (3) a slightly curved line, from the apex to the left edge of the sternum between the second and third costal cartilages. The whole of that part of the heart which lies to the right of the middle line is overlapped by pleura; on the left side, while a large portion of the heart is overlapped, a small area of pericardium is left uncovered by the pleura. This area may be marked out on the

surface by three lines, one drawn down the middle of the sternum, from the level of the fourth costal cartilages to the upper end of the ensiform process, the other two connecting the extremities of the first with the site

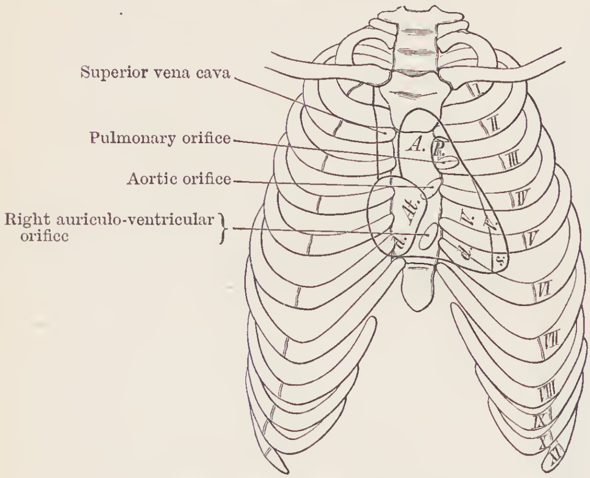


FIG. 313.—THE POSITION OF THE HEART WITH REFERENCE TO THE CHEST WALL. (C. Gegenbaur.)

of the apex. This area lies under the inner extremities of the fourth, fifth, and sixth intercostal spaces of the left side.

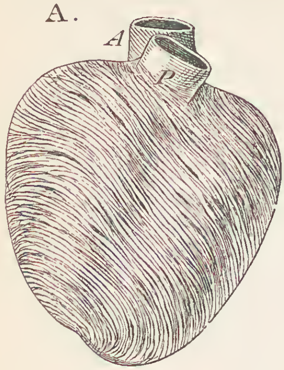
The aortic opening lies behind the left border of the sternum at the lower edge of the third left costal cartilage; the pulmonary orifice is above and to the left of the aortic, at the left border of the sternum, at the level of the upper edge of the third left costal cartilage. The left auriculo-ventricular opening lies behind the fourth left costal cartilage and the adjacent portion of the sternum; the right auriculo-ventricular orifice is placed behind the left half of the sternum at the level of the fifth costal cartilage.

The structure of the heart wall. The wall of the heart is chiefly formed of muscular tissue, but in the region surrounding the auriculo-ventricular and arterial openings there is a quantity of fibrous tissue, which encircles the orifices and becomes continuous with the tissue of the valves, sends a process downwards into the septum, and gives attachment to most of the muscular fibres. Superficially the heart is covered by the visceral pericardium or *epicardium*, while internally the cavities are lined by a smooth delicate membrane, the *endocardium*, which is continuous with the tunica intima of the vessels. A variable and, in some cases, a considerable amount of fat is found lodged under the pericardium, chiefly at the base of the heart, and in the course of the different furrows.

The *walls of the auricles* are much thinner than those of the ventricles. A superficial set of fibres, common to both auricles, runs transversely in front and behind, but is better marked in front; some of the fibres of this layer pass into the septum. Of the deeper fibres, which are proper

to each auricle, some form vertical loops attached below to the fibrous tissue which surrounds the great orifices, others, running transversely, encircle each cavity and take part in forming the partition; of this group a special band surrounds the fossa ovalis. Circular fibres are likewise found in the walls of the appendices and surrounding the openings of the veins.

A.



B.

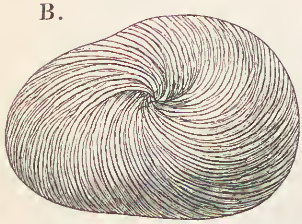


Fig. 314.—Superficial Layer of the Muscular Fibres of the Heart. *A*, From before. *B*, From the apex. (C. Gegenbaur.)

The arrangement of the muscular tissue of the *walls of the ventricles* is exceedingly complicated, and, as yet, is far from being thoroughly understood. The muscular bundles are quite distinct from those of the auricles; all of them probably take origin from the centrally placed fibrous tissue. Passing from the base, they descend towards the apex of the ventricles, and, forming twisted loops, ascend again towards the base, to be attached there, either directly, or indirectly through the chordae tendineae. Many of the bundles in the centre of the substance of the wall seem to have an almost transverse course, and, on careful dissection, the wall may appear to be made up of an almost indefinite number of layers, so gradual is the change in the direction of the sheets of fibres. While the wall of the left ventricle contains many fibres which are confined to itself, the great majority of the fibres of the right ventricle are continuous with fibres which belong also to the left ventricle. The superficial layer over the whole surface of both ventricles descends towards the apex of the heart, where its fibres twist upon themselves, forming a whorl, and ascend as the musculi papillares and the deepest layer of the left ventricle; the superficial descending fibres of the front of the heart ascend in the posterior wall of the left ventricle, those of the back in the anterior wall. An intermediate stratum of fibres descends from the base towards the apex of the left ventricle; many of the fibres of this set, twisting upon themselves, ascend again in the septum or in the wall of the left ventricle; others, however, cross in the septum and ascend in the wall of the right ventricle, forming its deeper layers and its musculi papillares. Some of the fibres of this intermediate layer have an exceedingly oblique, indeed, almost a transverse course. Speaking generally, the wall of the left ventricle may conveniently be divided into two layers descending from right to left, superficial to a transverse set, and two with an opposite obliquity, deeper than the transverse; while on the right side, it may be sufficient to recognize two oblique layers, and an intermediate transverse layer.

Vessels and nerves. The heart is supplied by the coronary arteries, the branches of which penetrate the muscular substance in all directions. The fibrous tissue of the valves, and the whole endocardial lining layer are non-vascular. The lymphatics are very numerous, and pass to the glands on the deep surface of the aorta. The nerves come from the superficial and deep cardiac plexuses; the ventricular branches have numerous minute ganglia beneath the pericardium.

Size and weight. In a state of moderate distension the heart measures about $5\frac{1}{2}$ inches in length, $3\frac{1}{2}$ in breadth, $2\frac{1}{2}$ in thickness. In an adult man it weighs about 11 oz., in the female about 9 oz. At birth it is about $\frac{1}{130}$th of the body weight, in adult life from $\frac{1}{170}$th to $\frac{1}{180}$th.

Pericardial connections (Fig. 315). The visceral layer of the pericardium, as it leaves the vessels and is continued into the parietal layer, forms a *mesocardial fold*, made up of two portions, an anterior or arterial, and a posterior or venous, which were primitively connected with one another by a fold which afterwards became obliterated, leaving a passage termed the *transverse sinus of the pericardium.*

The arterial part surrounds the aorta and pulmonary artery, for the distance of about two inches, with a complete pericardial tube.

The venous part is formed of two limbs continuous with one another, the one ascending and the other transverse in direction, and at the angle between the two the superior vena cava lies, surrounded except for a narrow strip behind. The ascending limb runs along the posterior margin of the right auricle, beginning below at the inferior vena cava, which is partially covered by the membrane, below and in front, for about half an inch, and inclosing higher up the right pulmonary veins, which are covered, except posteriorly, for about $\frac{1}{4}$th of an inch. The transverse limb passes to the left, along the upper border of the left auricle. It broadens out at the extremity, and presents three folds, the two lower for the left pulmonary veins, which, except posteriorly, are inclosed for about $\frac{1}{4}$th of an inch; the highest, the vestigial *fold of Marshall*, contains a vestige of the left superior vena cava.

THE ARTERIES AND VEINS.

THE PULMONARY ARTERIES AND VEINS.

The **pulmonary artery** springs from the heart at a spot opposite the upper margin of the third left costal cartilage at the border of the sternum. About two inches in length, it is directed upwards and backwards, and, dividing into right and left branches, terminates immediately beneath the arch of the aorta, under cover of the second left costal cartilage, and opposite the body of fifth dorsal vertebra. It is separated from the chest wall by the pericardium and by the left pleura. It lies at first in front of the ascending portion of the aorta, and then to the left

side of it and, in company with it, is surrounded in its whole length by a complete pericardial sheath. The left auricle is placed behind it, and the coronary arteries and the auricular appendices lie on its sides, at its commencement.

The branch for the right lung, longer and somewhat larger than that for the left, passes transversely behind the aorta and superior cava, and in front of the oesophagus, and divides in the root of the lung into two branches, the lower and larger of which is distributed to the middle and lower lobes. The branch for the left lung passes outwards and backwards, in front of the descending aorta, and divides in the root into two branches for the upper and lower lobes respectively. From its commencement there passes upwards to join the under side of the aortic arch a short fibrous cord, the *ligamentum arteriosum*, the remains of the *ductus arteriosus*, which in foetal life formed the main continuation of the pulmonary artery. In the roots of the lungs the arteries lie behind the upper veins, and in front of the bronchi; but the left artery, somewhat higher than the right, lies in a plane above the bronchus; the right branch lies below the bronchus, between it and the vein.

The **pulmonary veins** are four short trunks, each about half an inch in length, an upper and a lower on each side. Those of the right side pass behind the superior vena cava and the right auricle, those of the left in front of the descending aorta. In the root of the lung on each side the veins are placed lower than the other structures, and the higher of the two is likewise the most anterior of the different constituents.

SYSTEMIC ARTERIES.

THE AORTA.

The aorta (Fig. 317) passes at first upwards and to the right, then transversely to the left and backwards, and finally descends along the vertebral column as far as the middle of the body of the fourth lumbar vertebra, opposite which it terminates by dividing into the common iliac arteries. The descending portion is partly thoracic, partly abdominal. The vessel at its commencement is, in normal circumstances, slightly smaller in calibre than the pulmonary artery, and in its course it gradually diminishes, numerous branches being given off.

The **ascending portion of the aorta** springs from the heart opposite the left border of the sternum, at the level of the lower edge of the third left costal cartilage; it is directed, with a slight curve, upwards, forwards, and to the right, and at the right border of the sternum at the attachment of the second right costal cartilage, the spot at which it most nearly approaches the surface, passes into the transverse portion. It is a trifle over two inches in length. It presents, at its base, three dilatations corresponding to the sinuses of Valsalva; there may also be a certain enlargement, the *great sinus of the aorta*, running along the whole length of its right or convex border.

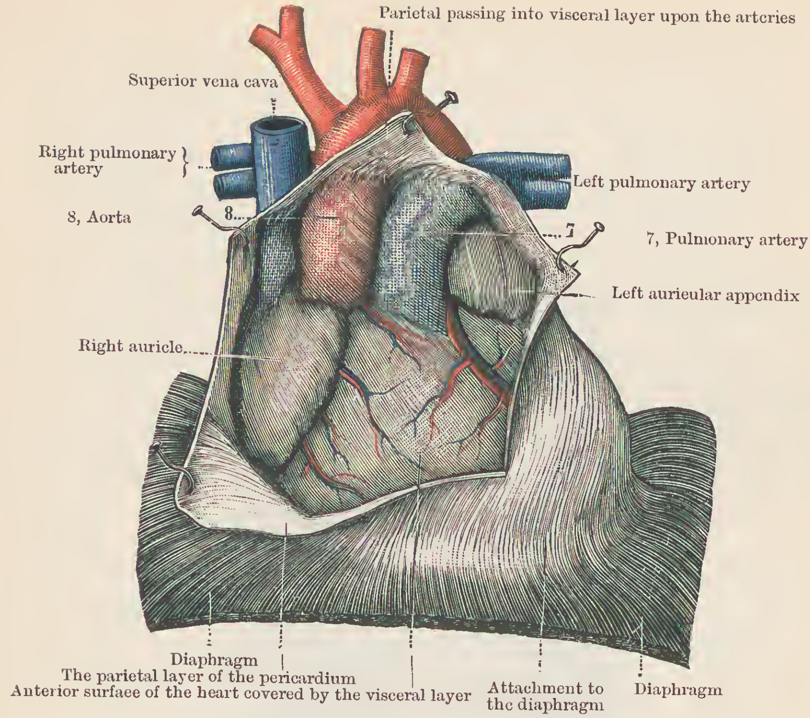


FIG. 315.– THE HEART WITHIN THE PERICARDIUM. The parietal layer of the pericardium cut through in front. (L. Testut.)

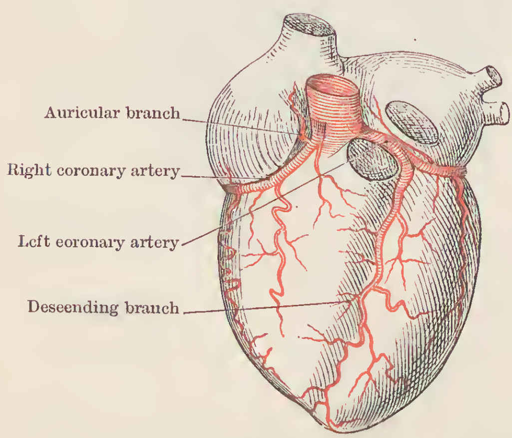


FIG. 316.—CORONARY ARTERIES, from in front and above. (C. Gegenbaur.)

To face p. 410.

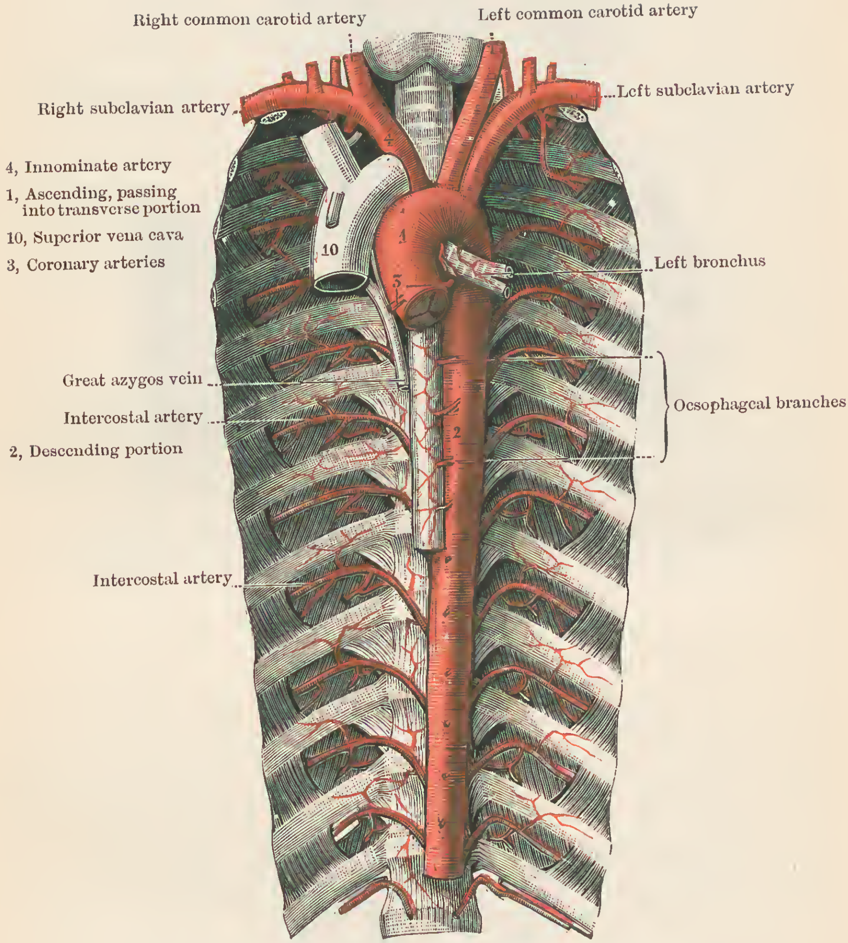


FIG. 317.—THE AORTA, thoracic portion. (L. Testut.)

To face p. 411.

The pulmonary artery lies at first in front, but afterwards to the left of it, and both are enveloped in a common tubular pericardial sheath. The left auricle and the right pulmonary artery lie behind it, the superior vena cava is placed to its right side, and the right auricular appendix lies in front near its commencement. It is separated from the sternum by the pericardium and by the right pleural sac. The branches of this portion of the aorta are the coronary arteries of the heart.

The *right coronary artery* (Fig. 316) springs from the right sinus of Valsalva. Emerging between the pulmonary artery and the right auricular appendix it passes along the auriculo-ventricular furrow until it reaches, on the posterior aspect of the heart, the posterior interventricular groove. It then divides into two, one division descending in the interventricular groove towards the apex, the other passing transversely still further onwards in the auriculo-ventricular furrow. Of the numerous branches given off previous to the division, the largest descends towards the apex along the margo acutus; others ramify upon the surface of the auricles and ventricles, and the basal portions of the great arteries.

The *left coronary artery* springs from the left sinus of Valsalva. It passes between the pulmonary artery and the left auricular appendix, and divides into two branches, one descending, the other transverse. The former passes downwards in the anterior interventricular groove towards the apex; the latter passes along the auriculo-ventricular furrow towards the transverse branch of the right artery. Numerous branches are supplied to the surface of the ventricles and auricles and the basal portions of the great arteries; one of considerable size descends towards the apex along the margo obtusus.

The **transverse portion of the aorta** passes backwards and to the left, and is curved with the convexity upwards. It commences opposite the right border of the sternum at the place of attachment of the second costal cartilage, and passes at first upwards and to the left behind the lower half of the manubrium. As it crosses, it gradually recedes from the breast bone, and reaches the left side of the body of the fourth dorsal vertebra, to the lower border of which it descends. It therefore forms an arch obliquely placed from right to left and from before backwards. The upper border of the arch corresponds with the line between the upper and lower halves of the manubrium. Some fatty tissue, remains of the thymus gland, lies in front of it, and it is overlapped, slightly on the right side and to a considerable extent on the left, by the corresponding pleural sacs. Behind it lie the trachea, oesophagus, and thoracic duct. The left bronchus passes outwards beneath it. It overhangs the bifurcation of the pulmonary artery, with the left branch of which it is connected by the ligamentum arteriosum. The left innominate vein lies along its upper edge at its anterior part, and the left superior intercostal vein crosses it anteriorly. It is also crossed in front by the left phrenic and pneumogastric nerves and by the superficial cardiac nerves; the

recurrent laryngeal branch of the left pneumogastric turns round beneath it and passes upwards towards the neck behind it. The deep cardiac plexus lies behind it, between it and the trachea; the superficial cardiac plexus lies beneath it, between it and the pulmonary artery. Many lymphatic glands lie behind and beneath it.

Three large branches—the innominate, left carotid, and left subclavian—are given off from its convexity. The ligamentum arteriosum is attached to its lower border immediately beyond the place of origin of the left subclavian artery.

Varieties of the aorta are very numerous, but most of them are to be explained by slight variations in the growth of different parts of the vessel; thus, neighbouring branches may be approximated to or even connected basally with one another, or, on the other hand, they may be unduly separated from one another. In the same manner some of the nearer derivatives of the main branches are sometimes transferred to the aorta itself, the most common case being that of the left vertebral artery. Occasionally it is the right vertebral which is so transposed, and among other arteries the internal and external carotids (the common carotid being absent), the thyroidea ima, the inferior thyroid, and the internal mammary have been, in special cases, noted as springing from the aorta. Slight variations in the exact position of the arch are not infrequent, and it may be placed either higher or lower than usual.

Among the more important malformations are some which depend on very early developmental changes, and will be best understood by the student after reference to the chapter on the development of the primary vessels. Sometimes the trunk arches to the right instead of to the left side, a variation which is occasionally accompanied by a transposition of the viscera generally, and depends on the survival of the right aortic root of the embryo instead of the left. In very rare cases both right and left arches have been found present. The right subclavian is occasionally the last of the great branches arising from the arch, and in this case the fourth right arch, which forms the usual root of the right subclavian, has disappeared, but, on the other hand, the right aortic root has remained patent and forms the basal portion of the vessel; with this malformation it has been noticed that frequently the thoracic duct opens into the great veins of the right side instead of into those of the left. A number of malformations of such a very serious nature as to be inconsistent with life have been found in foetuses. They are chiefly interesting from the light which they throw on early developmental processes.

The Innominate Artery.

The innominate artery arises from the aorta opposite the middle point of the manubrium. It passes upwards and to the right, and terminates immediately behind the right sterno-clavicular articulation by dividing

into the right subclavian and right common carotid arteries. Some remains of the thymus gland lie in front of it. It lies behind the sternum and the origins of the sterno-hyoid and sterno-thyroid muscles. It is placed at its commencement in front of the trachea, and higher up by the side of the trachea; at its right side it is in contact with the right pleura. The left innominate vein crosses it, and the right innominate vein and the right pneumogastric nerve lie by its right side. Occasionally a small branch, the *thyrodea ima* artery, passing upwards in front of the trachea to the thyroid body, springs from it.

The Common Carotid Arteries.

The **left common carotid artery** (Fig. 317) arises from the arch of the aorta, behind the middle of the manubrium, being placed at its origin immediately to the left of the innominate artery. It passes upwards and to the left, and enters the neck behind the left sterno-clavicular articulation. It lies behind the first piece of the sternum and the origins of the sterno-hyoid and sterno-thyroid muscles; remains of the thymus gland lie upon it, and it is crossed in front by the left innominate vein. It rests at first upon the anterior surface of the trachea, and afterwards, by the side of the trachea, upon the oesophagus, which deviates at the root of the neck a little to the left side. The thoracic duct lies behind it. The thoracic part of the left subclavian artery lies further back and to the left of this portion of the vessel, and the left pneumogastric nerve is a little external to it.

The **common carotid arteries in the neck** (Fig. 318) ascend, without branching, in front of the cervical transverse processes, as far as the fourth vertebra, where, on a level with the upper border of the thyroid cartilage, they divide into the external and internal carotid arteries. The course may be marked on the surface by a line drawn upwards from the sterno-clavicular articulation towards a point midway between the mastoid process and the angle of the jaw. The artery is crossed a little above its middle, at the level of the cricoid cartilage, by the anterior belly of the omo-hyoid muscle; the part of the vessel below the crossing, lying by the side of the trachea, is deeply placed; the part above, by the side of the larynx, is comparatively superficial. In its whole course the artery, accompanied by the internal jugular vein and the pneumogastric nerve, is surrounded by a sheath derived from the cervical fascia. Each structure occupies a separate compartment in the sheath; the vein lies external to the artery, close to it, with a tendency below to separate a little from it on the right side, and to overlap it slightly on the left; the nerve lies behind and between the vessels. The sheath rests behind on the origins of the longus colli and scalenus anticus muscles; the sympathetic nerve lies behind it along its whole length, and the inferior thyroid artery and the recurrent laryngeal nerve cross obliquely behind it in the lower part

of the neck. In front of the sheath, in immediate contact with it, the descending branch of the hypoglossal nerve passes downwards. In the region beneath the level of the cricoid cartilage, the sterno-hyoid, sterno-thyroid, and sterno-mastoid muscles cover the sheath; immediately above the level of clavicle the anterior jugular vein crosses outwards in front of the sheath, separated from it by the sterno-thyroid and sterno-hyoid muscles; a little higher up a middle thyroid vein, in many cases, crosses in front of the artery. At the level of the cricoid cartilage the sheath lies immediately under cover of the anterior border of the sterno-mastoid muscle, and is crossed by the omo-hyoid muscle. Above the cricoid cartilage the artery is, in normal circumstances, slightly overlapped by the anterior edge of the sterno-mastoid muscle. In this region a slender arterial twig (the sterno-mastoid branch of the superior thyroid) descends in front of the sheath, and one or more superior thyroid veins also cross it superficially.

The place of division of the common carotid artery is sometimes found a little higher than usual. Occasionally one or more of the earlier branches of the external carotid artery spring from the upper end of the common carotid. Important variations of the vessel are not common. Its absence has been noted, the external and internal carotid arteries springing directly from the aorta.

The External Carotid Artery.

The external carotid artery (Figs. 318, 319) passes upwards from the place of division of the common carotid, at the level of the upper border of the thyroid cartilage, to a spot immediately below and behind the neck of the lower jaw, where it divides into its terminal branches, the internal maxillary and temporal. At its upper extremity it is lodged in the parotid gland, and lies upon the surface of the styloid process. It has no companion vein. It first lies internal to the internal carotid artery but afterwards becomes superficial to it, and, while it is in contact with it below, it is separated from it above by the styloid process. Below the styloid process, the stylo-pharyngeus muscle and the glosso-pharyngeal nerve pass downwards and forwards on the deep surface of the external carotid, between it and the internal carotid. Below the angle of the lower jaw it is crossed superficially from above downwards and behind forwards by the stylo-hyoid and the posterior belly of digastric; below the crossing it is comparatively superficial, being only slightly overlapped by the anterior edge of the sterno-mastoid muscle; above it is deeply placed in the substance of the parotid gland. Below the digastric muscle it is crossed by the hypoglossal nerve and the lingual and facial veins. Above the crossing, in the substance of the gland, the facial nerve and temporo-maxillary veins are superficial to the artery. The external carotid gives off numerous branches, and rapidly diminishes in size.

The branches of the external carotid artery are the superior thyroid, the lingual, the ascending pharyngeal, the facial, the occipital, the posterior auricular, the temporal, and the internal maxillary.

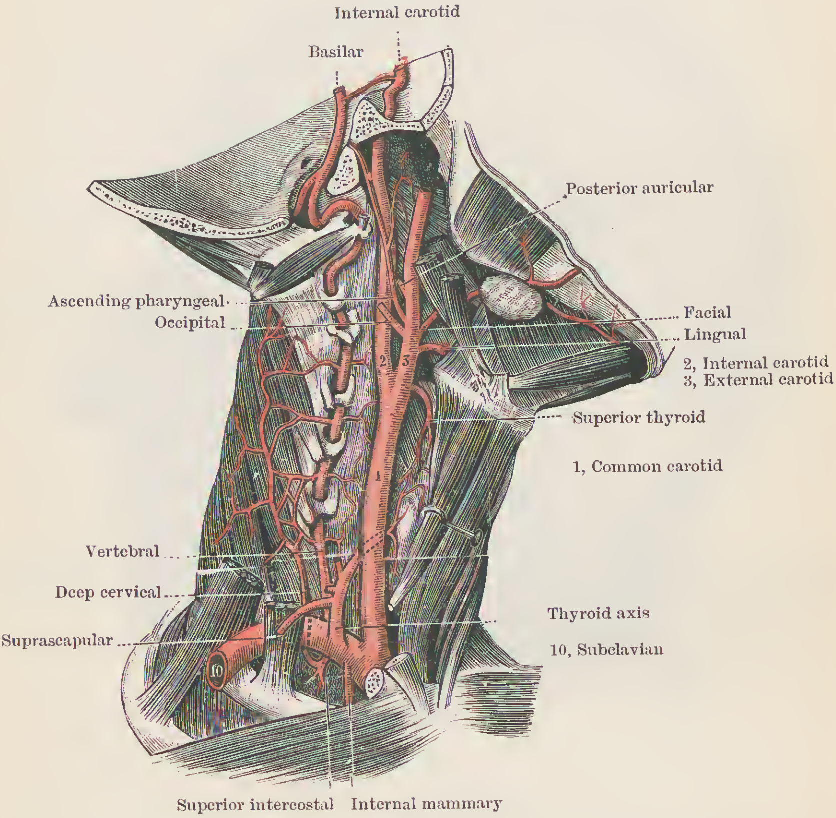


FIG. 318.—CAROTID AND SUBCLAVIAN ARTERIES OF THE RIGHT SIDE, AND THEIR BRANCHES. (L. Testut.)

To face p. 414.

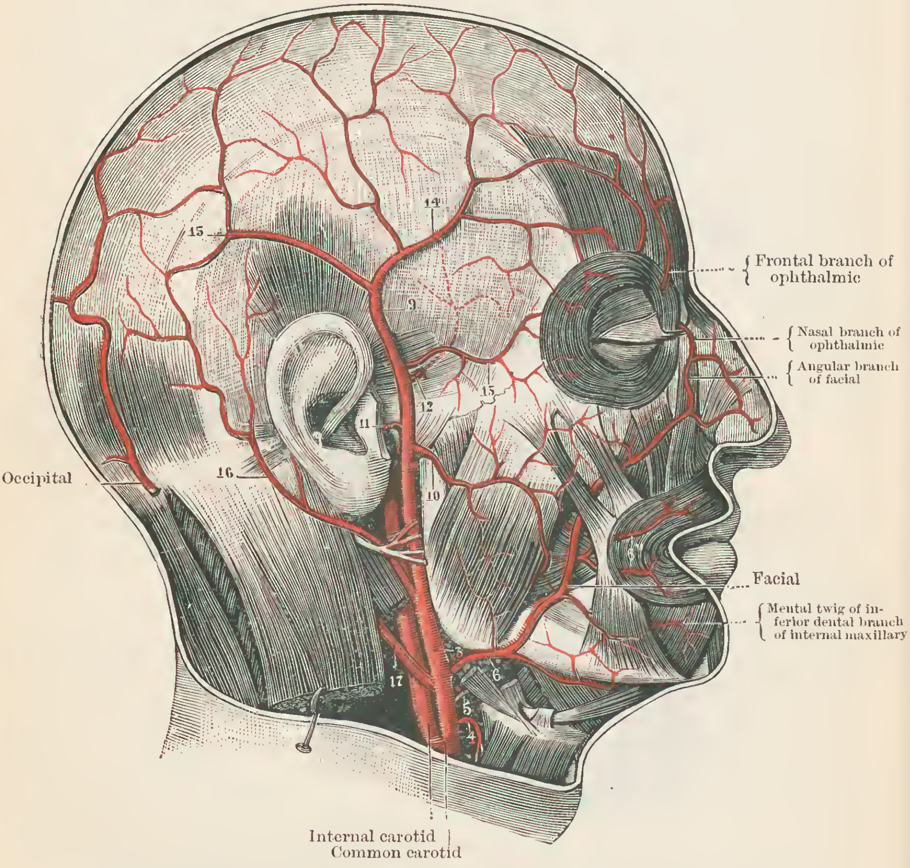


FIG. 319.—SUPERFICIAL ARTERIES OF THE HEAD. 3, External carotid; 4, superior thyroid; 5, lingual; 6, facial; 6″, coronary branches of facial; 9, temporal; 10, transverse facial branch of temporal; 11, anterior auricular branch of temporal; 12, middle deep temporal branch of temporal; 13, orbital branch of temporal; 14, frontal branch of temporal; 15, parietal branch of temporal; 16, posterior auricular; 17, occipital. (L. Testut.)

The **superior thyroid artery** (Figs. 318, 323) assists in supplying the thyroid body. It springs from the anterior border of the external carotid, close to its commencement, and arches at first forwards and downwards, and then descends under cover of the omo-hyoid, sterno-hyoid, and sterno-thyroid muscles. Its terminal branches ramify in the gland, anastomosing with the inferior thyroid branches of the same side, and to a slight extent also across the middle line with the arteries of the opposite side. In its course the superior thyroid artery furnishes the following branches: (1) the *hyoid*, a slender twig directed inwards on the thyro-hyoid membrane, immediately beneath the hyoid bone; (2) the *sterno-mastoid*, a small vessel, descending for a little distance in front of the carotid sheath; (3) the *superior laryngeal*, piercing the thyro-hyoid membrane along with the superior laryngeal nerve, and ramifying on the inner wall of the larynx; (4) the *crico-thyroid*, a very slender twig, but of importance on account of its position, as it may give rise to haemorrhage in the operation of laryngotomy, passing, as it does, towards the middle line on the crico-thyroid membrane, close to the lower border of the thyroid cartilage.

The **lingual artery** (Figs. 318, 323) springs from the anterior border of the external carotid, opposite the great cornu of the hyoid bone, and passes forwards on the deep surface of the hyo-glossus muscle to the tongue, but does not pursue a straight course. Close to its origin, it forms a small arch with the convexity upwards, and is crossed by the hypoglossal nerve; thereafter, directed forwards, it runs above the great cornu of the hyoid bone at a lower level than the nerve; then, at the anterior border of the hyo-glossus, it bends sharply upwards to reach the tongue, along the under surface of which, under the name of ranine artery, it is continued forwards. It rests successively upon the middle constrictor of the pharynx and the genio-glossus. It is crossed, near its origin, by the posterior belly of the digastric, and it is covered, further forwards, by the hyo-glossus muscle. Its named branches are: (1) the *hyoid*, a small twig which runs along the upper border of the hyoid bone; (2) the *dorsal artery or arteries of the tongue*, arising under cover of the hyo-glossus and piercing the posterior part of the tongue; (3) the *sublingual*, a branch of moderate size, supplying the sublingual gland and the surrounding parts. The *ranine artery*, giving off numerous branches, runs forwards with a tortuous course along the under surface of the tongue towards the tip; near its termination, by the side of the fraenum, it is very superficial. There is but little anastomosis between the vessels of opposite sides.

The **ascending pharyngeal artery** (Fig. 318), a long slender vessel, arises from the deep surface of the external carotid, about the level of the place of origin of the lingual artery. It passes upwards, to the base of the skull, upon the wall of the pharynx, crossing the deep surface of the stylo-pharyngeus muscle. It supplies delicate offsets to the prevertebral muscles, the wall of the pharynx, the tonsil, the Eustachian tube, and the palatal muscles. Its terminal branches enter the skull by the foramen

lacerum medium, the jugular foramen, and the anterior condylar foramen, and supply the dura mater.

The **facial artery** (Fig. 319) takes origin from the anterior border of the external carotid trunk, immediately above the lingual; it passes forwards and upwards, crosses the ramus of the lower jaw, and reaches the face. In the neck it rests, successively, upon the middle constrictor of the pharynx, the stylo-glossus, and the mylo-hyoid muscles; it is crossed superficially by the posterior belly of the digastric and the stylo-hyoid; and it passes along a groove on the deep surface of the submaxillary gland. Emerging from under cover of the gland, it crosses the jaw immediately in front of the anterior border of the masseter muscle. On the face it takes an exceedingly tortuous course, towards the inner canthus of the eye, crossing superficially the buccinator, levator anguli oris, and levator labii superioris muscles, and lying under cover of the platysma and zygomatici. Near its termination it usually passes through the substance of the common elevator of the lip and nose. On the face, branches of the facial nerve cross it superficially, and the infraorbital nerve emerges on its deep surface. The companion vein lies, on the face, external to and at some little distance from it; in the neck, the vein descends behind the artery and is more superficially placed.

(*a*) *Cervical branches.* The *tonsillar branch*, a long slender twig, ascends, crossing the outer surface of the stylo-glossus muscle, pierces the superior constrictor, and supplies small branches to the tonsil and the side of the tongue. The *palatine branch*, arising close to the tonsillar, ascends between the stylo-glossus and stylo-pharyngeus muscles, turns over the border of the superior constrictor, and descends with the levator palati to the soft palate. It gives numerous branches to the superior constrictor, the Eustachian tube, and the palate, and anastomoses with its fellow of the opposite side and with the descending palatine branches of the internal maxillary. *Glandular arteries* supply the submaxillary gland. The *submental artery*, a branch of some size, is given off by the facial immediately before crossing the jaw, and runs forwards on the surface of the mylo-hyoid muscle. It supplies the submaxillary gland, and detaches branches which, piercing the mylo-hyoid, reach the sublingual gland. Its terminal branches cross the ramus near the symphysis, and supply the muscles of the lower lip. It anastomoses with its fellow of the opposite side, the lingual, the inferior labial of the facial, and the mental branch of the internal maxillary.

(*b*) *Facial branches.* A number of muscular branches of small size anastomose with the buccal, transverse facial, and infra-orbital arteries. The other branches, which are specially named, are all given off from the anterior border of the parent trunk. The *inferior labial* artery runs forwards on the deep surface of the depressor anguli oris muscle, and supplies the lower lip and anastomoses with the sub-mental, mental, and inferior coronary vessels. The *coronary artery of the lower lip* arises below the angle of the mouth; the *coronary artery of the upper lip* arises above the angle of the mouth; each runs inwards near the margin of the lip,

between the muscle and the mucous membrane, to meet its fellow of the opposite side; the artery of the upper lip detaches a branch to the nasal septum. The *lateral nasal artery* ramifies upon the side of the nose, anastomosing with a branch of the ophthalmic artery. The *angular artery* is the terminal part of the facial at the inner canthus; it anastomoses with the nasal branch of the ophthalmic artery.

The **occipital artery** (Figs. 319, 323), arising opposite the facial, is directed upwards and backwards, and passes under cover of the posterior belly of the digastric muscle, on the deep surface of which it reaches the inner side of the mastoid process; continuing its course it runs backwards in the occipital groove, and crosses the lateral rectus and the superior oblique muscles; finally, at the posterior border of the splenius, becoming superficial, it turns upwards on the back of the head. The internal carotid artery, the internal jugular vein, the pneumogastric, spinal accessory, and hypoglossal nerves are crossed by the vessel on its way backwards, but the last named nerve loops round the artery from below, and, passing forwards, crosses it superficially close to its origin. The occipital artery gives off a number of *muscular branches*, the most important of which enters the sterno-mastoid. The *mastoid branch* enters a foramen in the mastoid and anastomoses with a branch from the posterior auricular. The *ramus cervicalis princeps*, or *descending cervical artery*, is given off under cover of the splenius; it divides into two branches, one of which ramifies on the deep surface of the splenius, while the other, passing under cover of the complexus, anastomoses with the deep cervical and vertebral arteries. The *terminal* branches, spreading over the back of the head, anastomose with one another, and with the posterior auricular and temporal arteries.

The **posterior auricular artery** (Fig. 319) takes origin from the external carotid a little above the occipital. It is directed upwards under cover of the parotid gland, crosses the styloid process, and, in the groove between the cartilage of the ear and the mastoid process, divides into its terminal branches, auricular and mastoid. It is crossed by the facial nerve. Some small branches pass to the parotid gland. The *stylo-mastoid* branch enters the stylo-mastoid foramen, and supplies twigs to the mastoid cells and to the tympanic walls, anastomosing with the tympanic branch of the internal maxillary artery. The *auricular* branch supplies both surfaces of the pinna of the ear. The *mastoid* branch bends backwards above the sterno-mastoid, and anastomoses with the occipital artery.

The **temporal artery** (Fig. 319) springs from the termination of the external carotid artery a little below the neck of the lower jaw. From its origin, where it is embedded in the parotid gland, it is directed upwards over the posterior root of the zygoma; about two inches above the zygoma, it divides into two branches, anterior and posterior, which ramify subcutaneously over the side of the head. The auriculo-temporal nerve, which, in its course through the gland, is placed internally to the artery, ascends

with it in front of the ear. The common temporal vein is behind and superficial to the artery as it crosses the zygoma.

Branches. The *transverse facial* artery arises in the substance of the parotid gland, and runs horizontally forwards above the duct of Stenson. It anastomoses with the facial, infraorbital, and buccal arteries. The *middle temporal* pierces the temporal fascia and the temporal muscle immediately above the zygoma, and ascends upon the surface of the bone, supplying the muscle and anastomosing with the deep temporal arteries. *Auricular* arteries, two or three in number, supply the fore part of the cartilage of the ear, anastomosing with the posterior auricular artery. The *anterior temporal* branch, directed upwards and forwards, ramifies over the anterior part of the lateral region of the scalp, anastomosing with branches of the ophthalmic artery; this is the branch usually chosen for temporal blood-letting. The *posterior temporal* branch, larger than the anterior, is directed upwards and backwards, and anastomoses with its fellow of the opposite side, and with the occipital and posterior auricular arteries.

The **internal maxillary artery** (Figs. 320, 321) springs from the termination of the external carotid artery immediately below the neck of the lower jaw. From its origin, where it is concealed in the substance of the parotid gland, it passes forwards, upwards, and inwards. In the first part of its course, accompanied by the internal maxillary vein, it passes on the deep surface of the ramus of the jaw, along the lower border of the external pterygoid muscle, crossing superficially the internal lateral ligament of the temporo-maxillary articulation and the inferior dental nerve. In the second part of its course it passes through the zygomatic fossa to the space between the heads of the external pterygoid muscle, crossing sometimes on the superficial and sometimes on the deep surface of the lower of the two heads of the muscle; in the former case it lies on the deep aspect of the temporal muscle at its insertion; in the latter it crosses the lingual nerve, and the internal pterygoid muscle, and emerges below the buccal nerve. In the third part of its course it passes through the pterygo-maxillary fissure to the spheno-maxillary fossa, where it breaks up into a number of branches. Numerous veins surround the second and third parts of the artery.

The *branches of the first part of the artery* enter bony foramina. The *tympanic* passes through the fissure of Glaser, ramifies on the walls of the tympanum, and anastomoses with the stylo-mastoid branch of the posterior auricular artery. The *middle meningeal*, a branch of considerable size, runs upwards on the deep surface of the external pterygoid muscle, passes between the heads of the auriculo-temporal nerve, and enters the skull by the foramen spinosum. Within the cranium, after detaching some small offsets which supply the Gasserian ganglion and enter the petrous bone, it continues upwards towards the anterior and lower angle of the parietal bone, where it divides into two branches which ramify upon the inner surface of

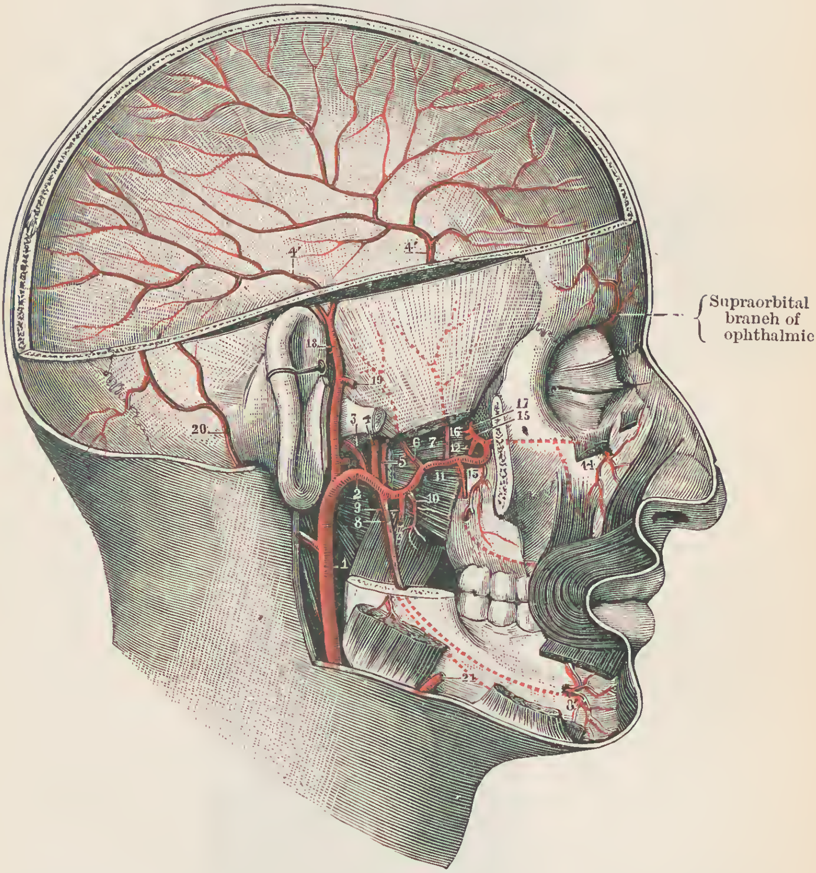


FIG. 320.—THE INTERNAL MAXILLARY ARTERY AND ITS BRANCHES. 1, External carotid artery; 2, internal maxillary artery; 3, tympanic; 4, 4′, middle meningeal; 5, small meningeal; 6, posterior deep temporal; 7, anterior deep temporal; 8, 8′, inferior dental; 9, 10, pterygoid; 11, buccal; 12, descending palatine; 13, posterior superior dental; 14, infraorbital; 15, Vidian; 16, pterygo-palatine; 17, spheno-palatine; 18, temporal artery; 19, middle deep temporal branch; 20, posterior auricular artery; 21, facial artery. (L. Testut.)

To face p. 418.

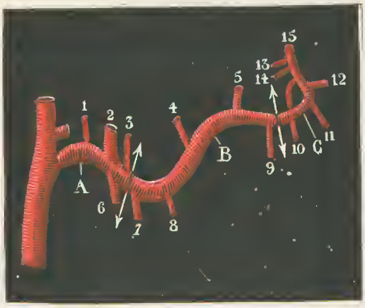


FIG. 321.—DIAGRAM OF THE BRANCHES OF THE INTERNAL MAXILLARY ARTERY. 1, Tympanic; 2, middle meningeal; 3, small meningeal; 4, posterior deep temporal; 5, anterior deep temporal; 6, inferior dental; 7, 8, pterygoid; 9, buccal; 10, descending palatine; 11, posterior superior dental; 12, infraorbital; 13, pterygo-palatine; 14, Vidian; 15, spheno-palatine. (L. Testut.)

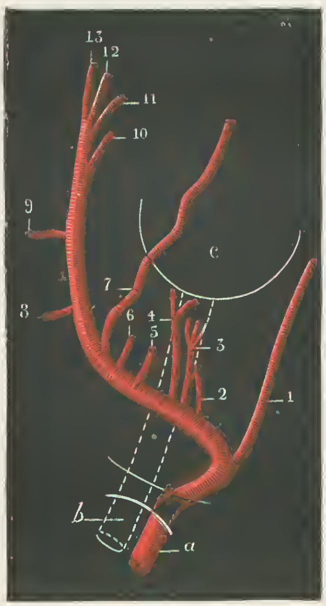


FIG. 322.—DIAGRAM OF THE BRANCHES OF THE OPHTHALMIC ARTERY. *a*, Ophthalmic artery; *b*, optic nerve; *c*, globe of the eye; 1, lachrymal; 2, central artery of the retina; 3, posterior or short ciliary; 4, middle or long ciliary; 5, superior muscular; 6, inferior muscular; 7, supraorbital; 8, posterior ethmoidal; 9, anterior ethmoidal; 10, superior palpebral; 11, inferior palpebral; 12, frontal; 13, nasal. (L. Testut.)

To face p. 419.

the skull, extending forwards to the frontal, backwards to the occipital bone, and upwards to the vertex. The *small meningeal* branch enters the skull by the foramen ovale, on the deep surface of the emerging nerve, supplies the dura mater of the middle fossa, and gives twigs to the Gasserian ganglion. The *inferior dental* branch descends, with the inferior dental nerve in the dental canal, supplying all the teeth of the lower jaw, and detaches a branch which, emerging by the mental foramen, terminates on the face in anastomosis with branches of the facial artery. Before entering the canal the artery detaches a mylo-hyoid branch, which runs along the mylo-hyoid groove and supplies the surrounding muscles; a small branch frequently descends for some distance with the lingual nerve.

The *branches of the second part of the artery* are distributed to the muscles of mastication, and are named in accordance with the individual muscles which they mainly supply. The *pterygoid* branches are irregular in number and size. The *deep temporal* are generally two, posterior and anterior; they pass upwards close to the bone in the substance of the temporal muscle, and anastomose with branches of the middle temporal artery, and, through the outer wall of the orbit, with derivatives of the ophthalmic artery. The *masseteric* branch usually springs from the posterior deep temporal artery; passing outwards through the sigmoid notch it enters the masseter muscle. The *buccal* artery ramifies on the buccinator muscle, and anastomoses with branches of the facial artery.

The *branches of the third part of the artery*, like those of the first, enter bony foramina. The *posterior superior dental* descends upon the surface of the superior maxillary bone, and detaches twigs which, entering the posterior dental canals, supply the molar and bicuspid teeth. The *infra-orbital artery* runs forwards in the infraorbital canal and, emerging by the infraorbital foramen, terminates on the face in branches which supply the surrounding parts, and anastomose with the facial and ophthalmic arteries; on its way forwards the artery detaches twigs to the orbit, and gives off an anterior superior dental branch, which descends in the anterior dental canal to complete the supply of the teeth, and gives, on its way, twigs to the membrane lining the maxillary antrum. The *superior or descending palatine* artery runs downwards, with the descending branches of Meckel's ganglion, in the posterior palatine canal, and is continued forwards along the hard palate towards the incisor foramen, through which its terminal branch ascends to anastomose with the naso-palatine artery; it detaches branches to the gums and the hard palate, and in addition gives off twigs which, descending through the smaller palatine canals, ramify in the soft palate, and anastomose with the ascending palatine branch of the facial artery. The *spheno-palatine artery* passes through the spheno-palatine foramen into the nasal fossa; its branches ramify in the nasal mucous membrane, and reach the frontal and maxillary sinuses; one, the naso-palatine, descends on the septum to anastomose with the terminal branch of the descending palatine artery. The *Vidian* branch passes backwards

along the Vidian canal, and gives branches to the pharynx, the Eustachian tube, and the levator palati muscle. The *pterygo-palatine*, a minute twig, passes backwards in the pterygo-palatine canal towards the upper part of the pharynx.

The Internal Carotid Artery.

The internal carotid artery (Fig. 323) stretches directly upwards from the termination of the common carotid artery to the carotid canal of the temporal bone, along which it passes to enter the skull. Within the skull it is distributed in branches to the brain and to the structures within the orbit. *In the neck* it lies at first behind and external to, but afterwards on the deep surface of the external carotid trunk. It is overlapped at first by the sterno-mastoid, then crossed by the digastric and stylo-hyoid muscles, and finally is very deeply placed on the inner aspect of the stylo-pharyngeus muscle, the styloid process, and the parotid gland. It ascends by the side of the pharynx, and rests behind upon the rectus capitis anticus major. The internal jugular vein is external and posterior to the artery, and the pneumogastric nerve lies behind the artery, between it and the vein, enveloped along with them in a common sheath. At the base of the skull, in addition to the pneumogastric nerve, the glosso-pharyngeal, spinal accessory, and hypoglossal nerves emerge between the artery and vein. The spinal accessory is soon directed backwards across the vein, the glosso-pharyngeal passes forwards superficially to the artery, and a little lower down, near the lower edge of the digastric muscle, the hypoglossal nerve, passing forwards, likewise crosses the artery superficially. On the deep surface of the artery the superior laryngeal branch of the pneumogastric crosses forwards. The superior cervical ganglion of the sympathetic lies behind the sheath. The occipital and posterior auricular arteries pass backwards superficially to the artery, the former below and the latter above the digastric muscle.

Within the carotid canal the artery is accompanied by the ascending branch of the superior cervical ganglion of the sympathetic, and is surrounded by a plexus of small veins. It passes at first upwards, then bends forwards and inwards. In the first portion of its course it is separated from the tympanum by the thin anterior part of the inner wall of the cavity. At the bend the bony portion of the Eustachian tube crosses it externally. Further forwards, where it is leaving the canal, it underlies the outer edge of the Gasserian ganglion, being separated from it by fibrous membrane only.

Within the cranium the artery at first, in continuation of its course on leaving the carotid canal, is directed forwards and inwards across the foramen lacerum medium; it then turns upwards in the groove on the side of the sphenoid, between the lingula and the petrosal process; it next passes forwards on the side of the body of the sphenoid, lying in the cavernous sinus, and invested by its lining membrane; and it finally turns upwards by the inner side of the anterior clinoid process, perforates the

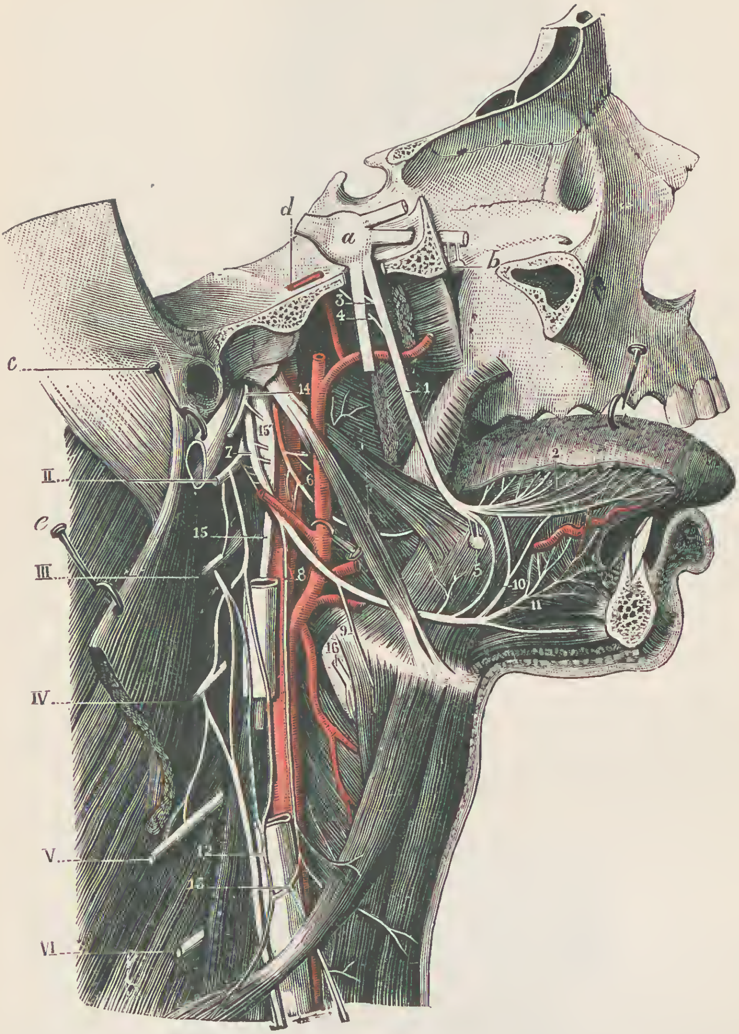


Fig. 323.—The External and Internal Carotid Arteries and their Chief Relations. II. to VI., Cervical nerves (anterior divisions). *a*, Gasserian ganglion; *b*, Meckel's ganglion; *c*, internal jugular vein; *d*, middle meningeal artery; *e*, sterno-mastoid muscle. 1, 2, Lingual nerve; 3, connecting branch between lingual and inferior dental; 4, chorda tympani; 5, submaxillary ganglion; 6, glosso-pharyngeal nerve; 7, hypoglossal nerve; 8, descendens hypoglossi: 9, thyro-hyoid branch; 10, connections between lingual and hypoglossal; 11, terminal branches of hypoglossal; 12, communicating branches from cervical plexus; 13, ansa hypoglossi; 14, spinal accessory; 15, pneumogastric; 15′, ganglion of the trunk of the pneumogastric; 16, superior laryngeal nerve. (L. Testut.)

To face p 420.

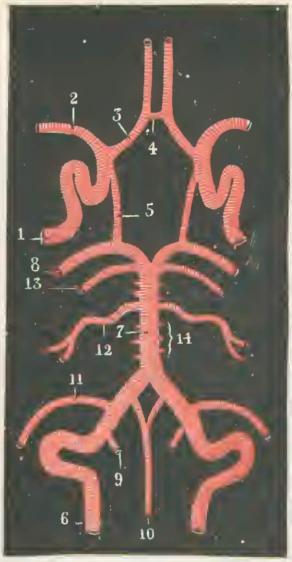


FIG. 324.—DIAGRAM OF THE ARTERIES OF THE BASE OF THE BRAIN. 1, Internal carotid; 2, middle cerebral; 3, anterior cerebral; 4, anterior communicating; 5, posterior communicating; 6, vertebral; 7, basilar; 8, posterior cerebral; 9, posterior spinal; 10, anterior spinal; 11, posterior inferior cerebellar; 12, anterior inferior cerebellar; 13, superior cerebellar; 14, transverse branches. (L. Testut.)

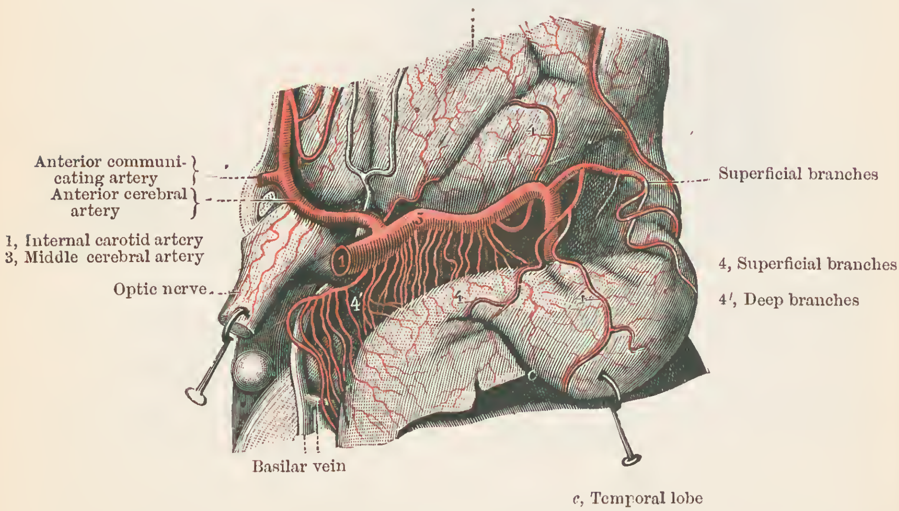


FIG. 325.—THE ANTERO-LATERAL GROUP OF DEEP BRANCHES FROM THE MIDDLE CEREBRAL. (L. Testut.)

To face p. 421.

roof of the sinus, and reaches the base of the brain in the neighbourhood of the anterior perforated spot. As it passes forwards in the sinus it is surrounded by filaments of the sympathetic, and is in contact externally with the third, fourth, ophthalmic division of the fifth, and sixth nerves.

There are no branches in the neck. Very minute twigs are detached in the carotid canal, and within the skull, to the tympanum and to the walls of the sinus. Immediately after perforating the roof of the sinus it detaches the ophthalmic artery, and at the base of the brain, before dividing into its terminal branches, the anterior and middle cerebral arteries, it gives off the posterior communicating and anterior choroid arteries.

The **ophthalmic artery** (Fig. 322), arising from the internal carotid as it ascends by the inner side of the anterior clinoid process, passes through the optic foramen below, and by the outer side of the optic nerve. Within the orbit it passes obliquely forwards and inwards with a slightly tortuous course, crossing in the posterior part of the cavity usually over, but sometimes under, the optic nerve. At the level of the pulley of the superior oblique muscle it divides into its terminal branches—the frontal and nasal. The branches are very numerous. A number of *muscular twigs* are given off irregularly from the main trunk and from its more important derivatives. The branches which are specially named may be divided into three groups, according as they are given off—(*a*) as the main trunk lies by the outer side of the optic nerve; (*b*) as it crosses the nerve; (*c*) as it is passing forwards along the inner wall of the cavity.

(*a*) The *lachrymal artery* runs forwards along the upper margin of the external rectus muscle to the lachrymal gland which it supplies. It detaches temporal and malar twigs, which pass through bony foramina to the exterior of the skull, in company with the similarly named branches of the superior maxillary division of the fifth nerve; and it likewise gives off slender palpebral branches to the upper and lower eyelids. The *central artery of the retina*, a slender vessel, leaves the ophthalmic artery at the back of the orbit, penetrates into the interior of the optic nerve, and, passing forwards within it, ramifies upon the retina.

(*b*) The *ciliary arteries* are divided into three groups—posterior, middle, and anterior. The posterior or short ciliary arteries, usually two in number at the origin, divide into ten or twelve branches, which pass forwards, surrounding the optic nerve, and pierce the sclerotic posteriorly; they ramify in the choroid coat. The middle or long ciliary arteries, two in number, arising either separately or with the posterior vessels, pierce the sclerotic posteriorly, one on either side of the optic nerve, a little in front of the short ciliary arteries, and are continued forwards to the iris. The anterior ciliary arteries, six or seven in number, may arise either directly or in conjunction with some of the muscular branches; they pierce the sclerotic anteriorly close to its corneal margin, and supply the ciliary processes of the choroid. The *supraorbital artery* passes forwards by the inner side of the levator palpebrae muscle, leaves the orbit by the supra-

orbital notch, in company with the supraorbital nerve, and ramifies upon the forehead, anastomosing with the temporal and frontal arteries.

(*c*) The *ethmoidal arteries* are two in number, anterior and posterior; they leave the orbit by the internal orbital canals. The posterior vessel, usually the smaller, is distributed to the upper and posterior part of the nasal mucous membrane. The anterior vessel, accompanying the nasal branch of the ophthalmic division of the fifth nerve, first detaches some small twigs to the dura mater of the anterior cranial fossa and then descends, supplying the fore part of the nasal mucous membrane. Its terminal twig appears externally on the side of the nose, having passed outwards between the lower edge of the nasal bone and the nasal cartilage. The *palpebral arteries*, two slender vessels, are distributed to the upper and lower eyelids respectively, and anastomose with branches of the lachrymal artery. The *frontal artery* (Fig. 319), one of the terminal branches, is directed upwards for a little distance on the forehead, anastomosing with its fellow of the opposite side and with the supraorbital artery. The *nasal artery*, the other terminal branch, ramifies over the root of the nose and anastomoses with the angular branch of the facial artery.

Arteries of the Cerebrum.

The arterial supply of the cerebrum is most conveniently described in sequence, although only the anterior and middle cerebral arteries are derived from the internal carotids, while the posterior cerebral arteries are right and left derivatives of the basilar, a mesial vessel formed by the union of the right and left vertebral arteries. An anastomotic connection between the main trunks at the base of the brain is called the circle of Willis: it is completed by the anterior communicating artery in front and the posterior communicating arteries at the sides posteriorly. Besides the anterior and middle cerebral arteries, the internal carotid usually gives off directly a slender vessel—the anterior choroid artery.

The **circle of Willis** (Fig. 324) is formed by the anastomosis of the branches of the basilar and internal carotid arteries at the base of the brain. The larger vessels which take part in its formation are the posterior cerebrals, internal carotids, and anterior cerebrals of opposite sides, and it is completed by the posterior communicating arteries stretching between the internal carotids and posterior cerebrals, and by the anterior communicating artery joining together the anterior cerebrals. It is heptagonal in form and within its area are placed from before backwards the optic commissure, infundibulum, corpora albicantia, and posterior perforated spot. It serves the purpose of equalizing the blood-pressure in the arteries distributed to the brain, and also maintains the supply to every part of the organ in cases of obstruction of one or other of the larger stems.

General distribution of the arteries of the cerebrum. The arterial branches which are distributed to the brain may be divided into superficial and deep groups. The *superficial branches* ramify in the pia mater

and finally give off very slender twigs which enter the surface of the brain. The neighbouring branches anastomose with one another in the pia mater, but the twigs which ramify in the brain substance have no anastomotic connection with one another. The superficial branches of the *anterior cerebral* artery supply the anterior and inner part of the orbital surface, the whole inner surface of the frontal lobe, the anterior and upper part of the outer surface of the frontal lobe, the whole inner surface of the parietal lobe, and the corpus callosum. The superficial branches of the *middle celebral* supply the posterior and outer part of the orbital surface, the posterior and lower part of the outer surface of the frontal lobe, the island of Reil, the whole of the outer surface of the parietal lobe, and the two upper convolutions of the outer surface of the temporal lobe. Those of the *posterior cerebral* supply the remaining part of the temporal lobe and the whole of the occipital lobe. A very small branch from the posterior communicating artery is given to the uncinate convolution of the temporal lobe. The choroid arteries belong to the superficial group; the largest of them, the anterior choroid, detaches numerous small branches to the optic thalamus and to the hippocampus major.

The *deep branches* are slender vessels which pierce the base of the brain and ramify chiefly in the basal ganglia, which they largely supply. Like the branches of the superficial arteries which enter the brain substance, they do not anastomose with one another. They are divided into six groups, an antero-mesial and a postero-mesial, and, on each side, an antero-lateral and a postero-lateral. The *antero-mesial group* is formed by a few branches from the anterior communicating and anterior cerebral arteries; they pass through the lamina cinerea and reach the anterior end of the caudate nucleus. The *antero-lateral group* (Fig. 325) springs from the middle cerebral artery; it is formed of numerous vessels which pierce the anterior perforated spot: they complete the supply of the caudate nucleus, and likewise pass to the lenticular nucleus, the external and internal capsules, and the anterior part of the optic thalamus. One of these vessels, somewhat larger than the others, and placed externally to them, has frequently been found ruptured, and has, in consequence, been named by Charcot, "the artery of cerebral haemorrhage." The *postero-lateral group* is formed of two or three small vessels which spring from the posterior cerebral artery on the outer side of the crus, and pass to the posterior part of the optic thalamus and to the corpora quadrigemina. The *postero-mesial group* is composed of five or six vessels which arise from the posterior cerebral arteries close to their origin, and pass upwards through the posterior perforated spot to the inner part of the crus and to the optic thalamus.

The **anterior choroid artery,** a small vessel, arises from the internal carotid trunk close to its extremity. It passes backwards, and, under cover of the uncinate convolution, to which it detaches some small branches, enters the extremity of the descending cornu; it ramifies in the choroid

plexus and detaches twigs to the optic thalamus and to the hippocampus major.

The **posterior communicating artery**, usually a slender trunk, but of very variable size and commonly unequal on opposite sides of the body, springs from the internal carotid immediately before its terminal division. It passes backwards, crossing the optic tract and crus cerebri, and joins the posterior cerebral artery. It gives off one or two slender branches to the crus and to the optic thalamus.

The **anterior cerebral artery**, from the termination of the internal carotid, runs forwards and inwards between the olfactory tracts and optic nerves to the great longitudinal fissure, where it approaches very closely its fellow of the opposite side with which it is put into communication by a short transverse trunk, the anterior communicating artery. Thereafter, in company with its neighbour, it courses in the longitudinal fissure, turning over the genu and runnning backwards upon the surface of the corpus callosum to anastomose with the posterior cerebral artery. Its branches are—(*a*) a few slender *deep branches* which, along with those of the anterior communicating artery, constitute the *antero-mesial group*; they pierce the lamina cinerea and supply the anterior end of the caudate nucleus; (*b*) a number of *superficial branches* of which (1) two or three *inferior frontal vessels* supply the anterior and inner part of the orbital surface of the frontal lobe; (2) two or three *internal frontal vessels* supply the mesial surface, and sweep over the margin of the hemisphere to supply the anterior and upper part of the outer surface of the frontal lobe; (3) *a parietal branch* supplies the inner surface of the parietal lobe; (4) an *artery to the corpus callosum.*

The **anterior communicating artery**, a transverse communication between the two anterior cerebral arteries, sometimes double, lies upon the lamina cinerea in front of the optic commissure and usually gives off two or three slender deep branches, which assist in supplying the fore part of the caudate nucleus.

The **middle cerebral artery** (Figs. 325, 326), the larger of the terminal divisions of the internal carotid artery, passes upwards and outwards in the fissure of Sylvius for a little distance, and then divides into its terminal branches which are superficial in their distribution. From the main trunk a number of *deep branches* are given off, constituting the *antero-lateral group.* These vessels supply the anterior part of the optic thalamus and the greater part of the candate nucleus, with the exception of the extreme fore part; they also supply the lenticular nucleus and the external and internal capsules. They pass through the anterior perforated spot. The terminal or *superficial branches* are four in number; they pass upwards between the convolutions of the island of Reil: (1) the *inferior frontal* supplies the posterior part of the orbital surface of the frontal lobe and the adjacent part of the third frontal convolution; (2) the *ascending frontal* supplies the lower and posterior part of the outer surface of the

frontal lobe; (3) the *parietal* supplies the anterior and upper parts of the parietal lobe; (4) *the parieto-temporal*, often double, the largest and most posterior, supplies the lower and posterior parts of the parietal lobe and sends branches downwards upon the first and second temporal convolutions.

The **posterior cerebral artery**, arising from the termination of the basilar artery at the anterior border of the pons, passes at first outwards across the crus in front of the third nerve, then turns upwards and backwards round the crus, and terminates on the under and inner surface of the hemisphere. As it is turning backwards it receives the posterior communicating artery. Its *deep branches* form (*a*) the *postero-median* and *postero-lateral groups*: the vessels belonging to the former, five or six in number, pass through the posterior perforated spot to supply the optic thalamus and the inner part of the crus; those belonging to the latter, two or three in number, pass upwards by the outer side of the crus to the optic thalamus and to the corpora quadrigemina; (*b*) some slender *branches to the crus* are detached as the main trunk lies on it. The *superficial branches* are—(1) the *posterior choroid arteries*, which supply the choroid plexuses and velum interpositum; (2) the *anterior temporal* which supplies the anterior part of the inner surface of the temporal lobe; (3) the *posterior temporal* which supplies the lower part of the outer surface, and the posterior part of the inner surface of the temporal lobe; (4) the *occipital* which supplies both surfaces of the occipital lobe.

Surgical anatomy of the common carotid artery and its branches. The course of the *common carotid* in the neck may be marked on the surface, by a line drawn from the sterno-clavicular articulation to a point midway between the angle of the jaw and the mastoid process. The vessel bifurcates opposite the upper border of the thyroid cartilage. It is crossed by the omo-hyoid muscle at the level of the sixth cervical vertebra, opposite the cricoid cartilage; below the crossing it is deeply placed, being covered by the sterno-mastoid muscle; above, it is comparatively superficial, being only overlapped by the anterior border of the muscle. The artery is reached through an incision made along its course, the centre being on a level with the cricoid cartilage. The head must be supported and the chin drawn upwards, and, in order to prevent the edge of the sterno-mastoid from being drawn completely over the vessel, only slightly turned to the opposite side from that on which the operation is to be performed. A descending branch from the facial vein may be met with at the anterior border of the sterno mastoid. The sterno-mastoid and omo-hyoid are to be clearly defined and drawn apart, and the sheath of the vessels exposed. On the surface of the sheath the superior thyroid veins, the sterno-mastoid branch of the superior thyroid artery, and the descendens hypoglossi nerve will probably be encountered. The sheath is to be opened over the artery, which is to be carefully separated from the walls. The hook is passed

from the outer side to avoid the vein, and care must be taken to prevent the inclusion of the pneumogastric nerve. A prominence of the costal process of the sixth cervical vertebra, the "carotid tubercle," is immediately behind the artery at the place of operation.

The course of the *internal carotid* artery is marked on the surface by the upper part of the carotid line already described. The incision, which is made along the anterior border of the sterno-mastoid muscle, extends upwards from the middle of the thyroid cartilage, as it is only the lower and comparatively superficial portion of the vessel which can be reached by the surgeon. The anterior border of the sterno-mastoid is drawn backwards, the posterior belly of the digastric and the hypoglossal nerve immediately below it are identified, and the position of the great cornu of the hyoid bone is recognized. The facial, lingual, and superior thyroid veins may cross the artery. The external carotid lies in close proximity, a little in front and a little internal; it must be drawn inwards. The needle is passed from without inwards, and care must be taken of the pneumogastric nerve; the superior laryngeal branch of the pneumogastric, and the sympathetic nerve lie on the deep surface of the sheath.

The *external carotid*, like the internal carotid, is deeply placed above, and is usually ligatured below the level of the digastric muscle, the portion of the vessel usually chosen being that which intervenes between the origins of the superior thyroid and lingual arteries. The line of the vessel in this region is practically the same as that of the internal carotid, and the steps in the operation for ligature are identical with those already described. The superior thyroid, lingual, facial, and occipital arteries may also be reached, at their places of origin, through the same incision.

The *lingual artery* is generally sought for in the second part of its course, under cover of the hyo-glossus muscle and immediately above the great cornu of the hyoid bone, the variability of the origin of the vessel and the difficulty of the operation rendering the ligature of the first part of the artery in most cases unadvisable. A curved incision is made from a point a little below and external to the symphysis, to a spot a little below the place where the facial artery crosses the lower jaw, the convexity reaching downwards as far as the upper margin of the great cornu of the hyoid bone. Some superficial veins may be met with; the submaxillary gland is exposed and carefully drawn upwards, the edge of the mylo-hyoid muscle is defined, and the intervening tendon of the digastric is drawn outwards. The hypoglossal nerve, with the ranine vein immediately below it, coursing upon the surface of the hyo-glossus is exposed. An incision through the muscle, a little below the nerve, between it and the great cornu, will expose the artery which is accompanied by two small venae comites.

The *facial artery* is usually ligatured at the place where it crosses the lower margin of the jaw, immediately in front of the masseter muscle. A

transverse incision is made across the line of the vessel. The vein lies behind the artery and in close proximity to it.

The *temporal artery* may be secured immediately above the zygoma; the companion vein lies behind and overlaps it.

The Subclavian Artery.

The subclavian arteries (Figs. 317, 318, 327) of the opposite sides differ from one another in their origin. The left artery arises within the thorax from the transverse portion of the aorta and, passing upwards, enters the neck behind the left sterno-clavicular articulation; the vessel of the right side springs from the extremity of the innominate stem, opposite the right sterno-clavicular articulation. Each vessel passes outwards in the neck with an upward arch over the apex of the lung, and, crossing under the clavicle and over the first rib, enters the axilla. The arch formed by the subclavian artery in the neck is placed above the inner half of the clavicle, and its summit reaches about an inch above the upper border of the collar bone, the arm hanging by the side. In its passage outwards the artery passes behind the scalenus anticus muscle; for convenience of description it is divided into three parts, the first internal to the muscle, the second behind it, and the third between the outer border of the muscle and the outer margin of the first rib. The first part of the left subclavian, including, as it does, the thoracic portion of the vessel, is about an inch longer than that of the right side.

The first part of the left subclavian artery. At its origin it lies a little behind and slightly to the left of the left common carotid artery, and the two vessels maintain their relative positions in their passage upwards to the neck. It lies behind but at some little distance from the left margin of the manubrium; the trachea lies to its right side; the oesophagus and the thoracic duct are behind it; and, on the left side and behind, it is covered by the pleura. In the neck it passes from behind the upper part of the sterno-clavicular joint outwards and upwards to the margin of the scalenus anticus muscle. The trachea, the oesophagus, the recurrent laryngeal nerve, and, at first, the thoracic duct, lie to its right side, but the duct, bending downwards and outwards to reach the innominate vein, afterwards crosses in front of it; the trunk of the sympathetic nerve and the longus colli muscle lie behind; the pleura is in contact with it below. It is covered in front by the sterno-mastoid, sterno-hyoid, and sterno-thyroid muscles. The subclavian and internal jugular veins unite in front of it to form the left innominate vein, and the vertebral vein descends to the innominate in front of it. The phrenic and some branches of the sympathetic nerves pass downwards into the thorax in front of it, and the pneumogastric nerve descends in front and a little to the right side.

The first part of the right subclavian artery arches upwards and outwards from the extremity of the innominate stem, behind the upper part of the right sterno-clavicular articulation, to the margin of the scalenus anticus

muscle. The sterno-mastoid, sterno-hyoid, and sterno-thyroid muscles cover it superficially; behind, it rests on the longus colli; the pleura is in contact with it below. The right subclavian and internal jugular veins unite in front of it to form the right innominate vein, and the vertebral vein descends in front of it. The pneumogastric and some loops of sympathetic nerve cross it superficially, and the recurrent laryngeal nerve, turning round it, passes upwards and inwards behind it; the main trunk of the sympathetic descends behind it.

The second part of the subclavian artery forms the highest part of the arch. It is covered in front by the scalenus anticus and sterno-mastoid muscles, and is in contact with the pleura below and behind; the brachial plexus lies above it. The subclavian vein is placed a little lower than the artery, and in front of it, being separated from it by the scalenus anticus. The phrenic nerve descends, on the right side, in front of the inner part of the second portion of the artery; on the left side, as already described, it runs downwards in front of the outer part of the first portion of the artery.

The third part of the subclavian artery extends downwards and outwards from the outer margin of the scalenus anticus to the outer margin of the first rib. It is the most superficial portion of the vessel and is likewise the longest of the three parts; it lies, under cover of the deep cervical fascia, in a triangular space, the sides of which are formed by the margins of the sterno-mastoid and omo-hyoid muscles, and the clavicle. Behind, it is in contact with the scalenus medius, and below, it rests upon the first rib. The subclavian vein is lower than, and in front of, the artery; and the external jugular vein, descending to the subclavian, crosses it superficially, receiving as it passes in front of the artery, the suprascapular and transverse cervical veins from the shoulder. The suprascapular artery running behind the clavicle crosses the third part of the subclavian, and the transverse cervical artery, passing outwards in the neck, lies above it. The brachial plexus lies above and behind it, the lowest cord being in close contact with it. The slender nerve to the subclavian muscle crosses it in front, and the supraclavicular branches of the cervical plexus descend in the superficial tissue in front of it.

The branches of the subclavian artery are—(1) the vertebral, (2) the internal mammary, (3) the thyroid axis, and (4) the superior intercostal artery. The three first mentioned spring from the first part of the artery, the last usually takes origin from the second portion; the third part, save in abnormal circumstances, gives off no branch.

(1) The **vertebral artery** (Fig. 318) arises from the upper border of the first part of the subclavian artery, a little distance from the margin of the scalenus anticus muscle. It is at first directed upwards and a little outwards to reach the foramen in the transverse process of the sixth cervical vertebra; it then passes almost directly upwards through the successive higher foramina, save that in passing from that of the second to that of the first vertebra it bends considerably outwards. After threading the trans-

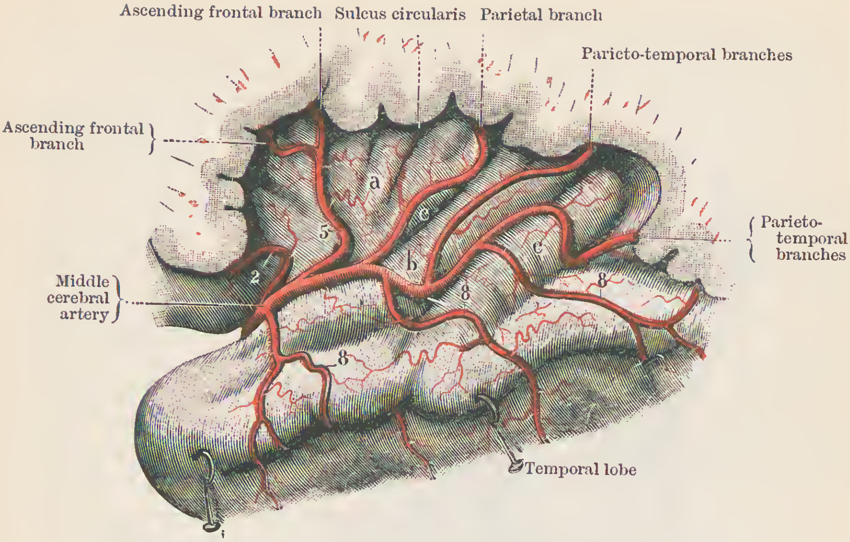


FIG. 326.—THE SUPERFICIAL BRANCHES OF THE MIDDLE CEREBRAL ARTERY. a, Anterior portion of island of Reil; b, posterior portion of island of Reil; c, sulcus centralis; e, parieto-temporal convolution; 2, inferior frontal branch; 5, ascending frontal branch; 8, temporal branches. (L, Testut.)

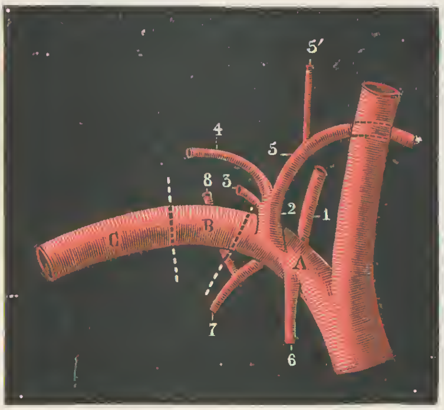


FIG. 327.—DIAGRAM OF THE METHOD OF ORIGIN OF THE BRANCHES OF THE RIGHT SUBCLAVIAN ARTERY. A, 1st part of subclavian; B, 2nd part of subclavian; C, 3rd part of subclavian; 1, vertebral artery; 2, thyroid axis; 3, suprascapular artery; 4, transverse cervical artery: 5, inferior thyroid artery; 5′, ascending cervical branch; 6, internal mammary artery; 7, superior intercostal artery arising, unusually, from the first part; 8, deep cervical artery. (L. Testut.)

To face p. 428.

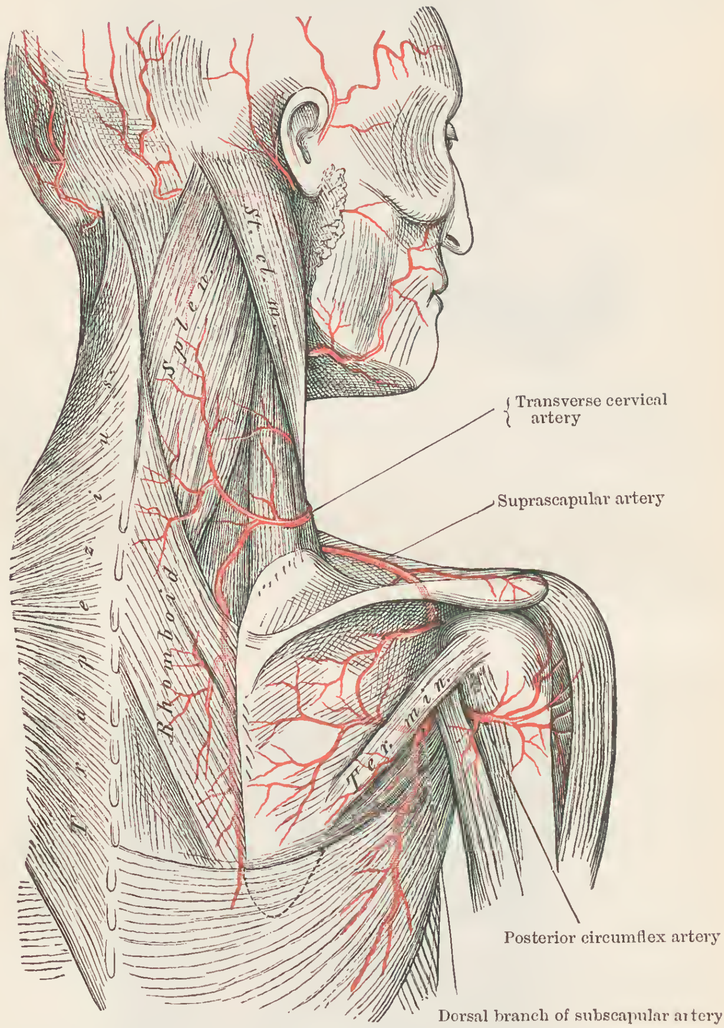


FIG. 328.—ARTERIES OF THE BACK OF THE SHOULDER. (C. Gegenbaur.)

To face p. 429.

verse process of the atlas, it turns backwards and inwards behind the superior articular process of that bone, occupying the groove on the posterior arch; then piercing the occipito-atlantal ligament, dura mater, and arachnoid, it reaches the side of the spinal cord. It then ascends through the foramen magnum, and runs forwards along the basilar process of the occipital bone, gradually approaching its fellow of the opposite side, with which, at the posterior border of the pons, it unites to form the *basilar* artery. Before entering the foramen of the sixth cervical vertebra, the artery lies between the origins of the scalenus anticus and longus colli muscles, and is covered in front by the internal jugular and vertebral veins. Ascending through the foramina, it passes in front of the issuing cervical nerve trunks, and is surrounded by filaments of the sympathetic nerve, and by a venous plexus. As it turns backwards, before entering the spinal canal, it lies in the occipital triangle, and the posterior primary division of the suboccipital nerve passes out beneath it. Within the subarachnoid space, it crosses the side of the medulla immediately below the roots of the hypoglossal nerve.

The branches of the vertebral artery in the neck are all of small size. The *spinal branches* pass towards the spinal canal, where they divide, supplying the bony walls, the membranes, and the cord. Numerous *muscular branches* ramify among the deeper muscles of the neck, and anastomose with branches of the ascending cervical, deep cervical, and occipital arteries. When piercing the dura mater the artery gives off a small *meningeal branch*, which ramifies in the posterior fossa of the skull. The *posterior spinal branch* is detached as the vertebral artery enters the cranium. It runs downwards upon the side of the cord, and divides into two slender vessels which form the commencement of lateral anastomotic chains of arteries. The *anterior spinal artery* arises near the extremity of the vertebral. It passes backwards upon the medulla, and unites with its fellow of the opposite side to form a median anastomotic arterial vessel, which runs downwards upon the cord. The *posterior inferior cerebellar artery* arises between the spinal arteries. It passes over the restiform body and reaches the vallecula, where it breaks up into branches, some of which supply the inferior surface of the cerebellum, while others ramify in the choroid plexus of the fourth ventricle.

The arteries of the spinal canal and spinal cord. Lateral arteries running along the issuing nerves enter the canal. They are derived from the vertebral, deep cervical, intercostal, lumbar, ilio-lumbar, and lateral sacral arteries. Each artery on reaching the canal divides into two branches, one of which ramifies on the bony wall, while the other, piercing the membranes, is continued towards the cord. The successive *branches which ramify upon the bony walls* communicate with one another and with the corresponding vessels of the opposite side, with the result that three longitudinal arterial anastomotic chains, one median and two lateral, communicating freely with one another by transverse branches, are formed on the posterior

surface of the vertebral bodies. The *branches which pass towards the cord* are in most cases small, and lose themselves upon the membranes and nerve roots, but a few, larger than the others, are continued into the longitudinal anastomotic vessels. The *anterior anastomotic vessel*, formed above by the junction with one another of the anterior spinal branches of the vertebrals, runs the whole length of the cord in front of the anterior median fissure, and is reinforced by seven or eight lateral branches. The *lateral anastomotic chains*, arising above from the posterior spinals of the vertebrals, are double on each side, one vessel lying in front of and the other behind the posterior nerve roots. They are smaller and more irregular than the anterior, but run the whole length of the cord, and are reinforced by occasional lateral branches.

The **basilar artery** (Fig. 324) extends forwards and upwards from the posterior to the anterior border of the pons, occupying a median groove on its under surface, and ends by dividing into the posterior cerebral arteries, which have been already described (p. 425). It gives off—(1) the *transverse arteries*, numerous small vessels, which pass outwards on either side, supplying the pons and adjacent parts of the brain; (2) the *internal auditory arteries*, one on each side, accompanying, in each case, the auditory nerve to the internal ear; (3) the *anterior inferior cerebellar arteries*, which ramify on the under surface of the cerebellum and anastomose with the posterior inferior cerebellars of the vertebral; (4) the *superior cerebellar arteries*, which arise at the extremity of the basilar, immediately behind the posterior cerebrals, and turning outwards behind the third nerves, wind round the crura, and are distributed in branches, some forwards to the isthmus cerebri and velum interpositum, and others backwards to the upper surface of the cerebellum, anastomosing with the inferior cerebellar arteries.

The arteries of the cerebellum, pons, medulla, and spinal cord ramify and anastomose with one another in the pia mater, and finally detach small twigs which pass into the nervous substance within which, like the ultimate derivatives of the cerebral arteries, their branches have no anastomotic connections with one another.

(2) The **thyroid axis** (Fig. 318) springs from the front of the first part of the subclavian, a little external to the place of origin of the vertebral artery. It is about a fourth of an inch in length, and divides into three diverging branches—the inferior thyroid, the transverse cervical, and the suprascapular.

The **inferior** or **ascending thyroid artery** passes from the thyroid axis upwards and inwards, in front of the vertebral artery, and behind the carotid sheath and the middle cervical ganglion of the sympathetic, to the lower and hinder part of the thyroid body, where its terminal branches ramify, anastomosing with those of the superior thyroid artery, and, to a certain extent, with those of the thyroid arteries of the opposite side. On its course the artery supplies *muscular*, *oesophageal*, and *tracheal branches*. An *inferior laryngeal* branch accompanies the recurrent laryngeal nerve to the

larynx. The *ascending cervical artery* is a long slender branch which is given off as the parent vessel is crossing behind the carotid sheath. It runs upwards, for a variable distance, in front of the transverse processes, and gives off small twigs which anastomose with branches of the vertebral and occipital arteries. The ascending cervical artery is somewhat variable in its origin, and may spring directly from the thyroid axis or from the transverse cervical artery. Occasionally it is of large size, and compensates, through its anastomosing branches, for deficiency in either the occipital or vertebral artery.

The **transverse cervical artery** (Fig. 328) passes outwards and a little upwards across the lower part of the neck as far as the anterior border of the levator anguli scapulae muscle, where it divides into the superficial cervical, and posterior scapular arteries. It crosses in front of the scalenus anticus and the brachial plexus, sometimes, however, threading its way between the nerve cords, and, passing behind the omo-hyoid, divides under cover of the anterior border of the trapezius. The *superficial cervical branch* ramifies on the deep surface of the trapezius. The *posterior scapular branch* crosses the deep surface of the levator anguli scapulae, and descends along the posterior border of the scapula, on the deep surface of the rhomboidei muscles, distributing numerous branches to both surfaces of the scapula and to the surrounding muscles. It anastomoses with the suprascapular and subscapular arteries, the intercostals, and the superficial cervical artery; a very constant branch passing between the rhomboidei muscles reaches the deep surface of the trapezius. The transverse cervical artery is very irregular; it frequently springs from the third part of the subclavian, or its posterior scapular branch may spring from the third part, while the superficial cervical has the course of the usual trunk.

The **suprascapular artery** (Fig. 328) descends towards the clavicle, and passes outwards along the posterior surface of that bone to the upper margin of the scapula; continuing its course, it crosses over the ligament which completes the suprascapular notch, and descends on the dorsal surface of the scapula, beneath the acromion, to the infraspinous fossa, where its terminal branches ramify. Its chief branches are *muscular twigs*, the *medullary artery of the clavicle*, and a *subscapular branch*, which, given off as the vessel crosses over the notch, descends on the ventral surface of the scapula. The suprascapular artery anastomoses with the other scapular arteries and with the acromio-thoracic.

(3) The **internal mammary artery** (Figs. 318, 345) arises from the lower border of the first part of the subclavian, usually opposite the place of origin of the thyroid axis. It descends, at first with an inclination forwards and inwards, and reaches the back of the cartilage of the first rib; afterwards it is continued directly downwards, about half an inch from the margin of the sternum, behind the successive rib cartilages, as far as the lower margin of the sixth interspace, where it divides into its terminal branches, the musculo-phrenic and the superior epigastric. In passing from the neck to the

thorax it crosses behind the subclavian vein, and is crossed in front, from without inwards, by the phrenic nerve. Within the thorax it lies on the deep surface of the internal intercostal muscles, and is at first in contact with the pleura behind, but lower down it is separated from the pleura by the triangularis sterni muscle. Two veins accompany it in the greater part of its course, but join with one another above to form a single vessel which lies by its inner side.

The branches of the artery are numerous, but small. The *comes nervi phrenici*, a long slender vessel, accompanies the phrenic nerve to the diaphragm, giving off slender twigs to the pericardium and pleura. The *mediastinal*, *pericardial*, and *sternal* branches form three sets of minute anastomosing vessels. The *anterior intercostals*, two in each of the first six intercostal spaces, run backwards, first on the deep surface of the internal intercostal muscles, and afterwards between the internal and external layers, to anastomose with the main intercostals and their collateral branches. The *perforating branches*, one in each of the first six intercostal spaces, become subcutaneous by the side of the sternum; the middle two or three of them supply the mammary gland, and are often much enlarged. The *musculo-phrenic*, one of the terminal branches, inclines outwards, downwards, and backwards behind the cartilages of the seventh, eighth, and ninth ribs, and, becoming much reduced in size, perforates the attachment of the diaphragm about the level of the tenth rib; it gives off anterior intercostals for two or three spaces, and, to the diaphragm, a number of muscular branches which anastomose with branches of the inferior phrenic artery. The *superior epigastric*, the other terminal division, enters the abdominal wall by the side of the ensiform process, descends behind the rectus muscle, within its sheath, and finally enters the substance of the muscle to anastomose with the deep epigastric artery. It gives off numerous small branches, muscular, cutaneous, and peritoneal in their distribution, and some which pass backwards within the fold of the falciform ligament to the liver. As a not infrequent abnormality, a branch of moderate size has been found springing from the upper part of the internal mammary, and descending on the inner aspect of the chest wall at some little distance from the main trunk; it has been named the *infracostal* artery.

(4) The **superior intercostal artery** arises, usually, from the back of the second part of the subclavian, close to the inner margin of the anterior scalene muscle, but frequently, however, especially on the left side, it springs from the first part of the main vessel. It passes at first backwards and gives off its deep cervical branch; it then descends over the neck of the first rib, lying internal to the sympathetic nerve, and supplies the first two intercostal spaces after the manner of an aortic intercostal. The *deep cervical branch* passes backwards, between the transverse process of the last cervical vertebra and the neck of the first rib, and, ascending behind the transverse processes, between the origins of the complexus and multifidus spinae, terminates by anastomosing with the ramus cervicalis princeps of the occipital artery. It gives

off numerous muscular branches which anastomose with twigs of the vertebral artery.

Surgical anatomy of the subclavian artery. The first and second parts of the artery are so deeply placed, and have such important connections, that, save in very exceptional circumstances, an operation upon them would hardly be considered justifiable. The third part of the vessel may, however, be easily reached. A horizontal incision is made across the lower part of the posterior triangle, about half an inch above the clavicle, from the posterior border of the sterno-mastoid to the anterior edge of the trapezius. In making this incision the surgeon usually draws downwards the skin of the neck and cuts through it against the clavicle. In the superficial fascia, the platysma and a number of the descending branches from the cervical plexus are met with, and, occasionally, a vein from the arm, a branch from or a continuation of the cephalic. At the posterior border of the sterno-mastoid the external jugular vein passes through the deep fascia, and receives on its outer side its suprascapular and transverse cervical tributaries which sometimes form a small plexus in front of the artery. They must be drawn aside or divided between ligatures. The posterior belly of the omo-hyoid muscle, with the transverse cervical artery coursing outwards immediately below it, is placed a little above the line of the subclavian; the suprascapular artery lies behind the clavicle; if necessary, these structures must be drawn aside. The edge of the scalenus anticus muscle is to be defined and the finger passed downwards along it to the scalene tubercle of the first rib. The artery emerges from behind the muscle and may, as a rule, be easily recognized. The cords of the brachial plexus lie above the artery and on a plane posterior to it, the lowest cord being in close proximity to it. The vein lies in front and below. The needle is passed from above downwards and behind forwards, between the lowest nerve-cord and the artery, and should be handled with great care, as there is danger of wounding the pleura. During the operation the clavicle should be kept depressed as much as possible.

The *vertebral artery* may be ligatured through an incision extending upwards from the clavicle for about three inches along the posterior border of the sterno-mastoid muscle. The external jugular vein and the sterno-mastoid are drawn inwards. The line between the longus colli and the scalenus anticus can be appreciated by the finger, and the carotid tubercle of the sixth vertebra can be easily recognized. The artery lies a little below the tubercle. Its vein lies immediately in front of it and must be pushed aside. The branches of the sympathetic nerve are to be separated as far as possible.

The *inferior thyroid* artery may be reached through an incision made along the anterior border of the lower part of the sterno-mastoid. The carotid sheath is to be drawn outwards. The artery passes inwards from behind the sheath, a little below the carotid tubercle.

The Axillary Artery.

The axillary artery (Fig. 329) is the continuation of the subclavian and extends through the axilla from the outer margin of the first rib to the lower border of the teres major muscle. It enters the axilla at the apex and is continued downwards along the outer wall in contact with the coraco-brachialis and biceps, and rests behind successively upon the first and second digitations of the serratus magnus, the subscapularis, the latissimus dorsi, and the teres major. In front it is covered, in the greater part of its extent, by the pectoralis major, and behind that muscle, in order from below upwards, by the pectoralis minor, and costo-coracoid membrane, and, when the shoulder is depressed, the subclavius muscle. It extends below the lower border of the pectoralis major for about an inch and a half and is there comparatively superficial. It is in close relationship with the axillary vein and the nerve-cords of the brachial plexus. For convenience of description it is divided into three parts: the first, about an inch in length, above the pectoralis minor; the second, a trifle longer, behind that muscle; and the third, about three inches in length, below its lower border.

The axillary vein lies internal to the artery in its whole length; the cephalic vein crosses in front of the first part of the artery; and one of the brachial venae comites frequently crosses in front of the third part. The three cords of the brachial plexus lie by the outer side of the first portion of the artery, but as they pass onwards they change their positions in relation to the vessel; the inner cord passes behind the artery and gains its inner side, where it lies between the artery and the vein; the posterior cord passes inwards and descends behind the artery; the outer cord approaches the artery and comes into contact with it externally. In the upper part of the axilla the nerve-cords detach one or two branches, and a little below the lower margin of the pectoralis minor they break up into their terminal divisions. The external anterior thoracic branch crosses in front of the first part of the artery, and the internal anterior thoracic passes forwards by the inner side of the second part, and the two nerves are connected with one another, forming a loop in front of the artery. The third part of the artery is crossed in front by the inner head of the median nerve; in contact with its outer side is the outer head of the median above and the completed trunk of that nerve below; with its inner side the internal cutaneous and ulnar nerves are in contact; the musculo-spiral nerve descends behind it. In addition to these, the posterior thoracic nerve (the nerve to the serratus magnus), which arises in the neck and passes into the axilla through the apex, lies for a little distance behind the first part of the artery. A number of lymphatic glands are in contact with the artery and its main branches. The branches of the axillary artery are inconstant both in number and size; the more

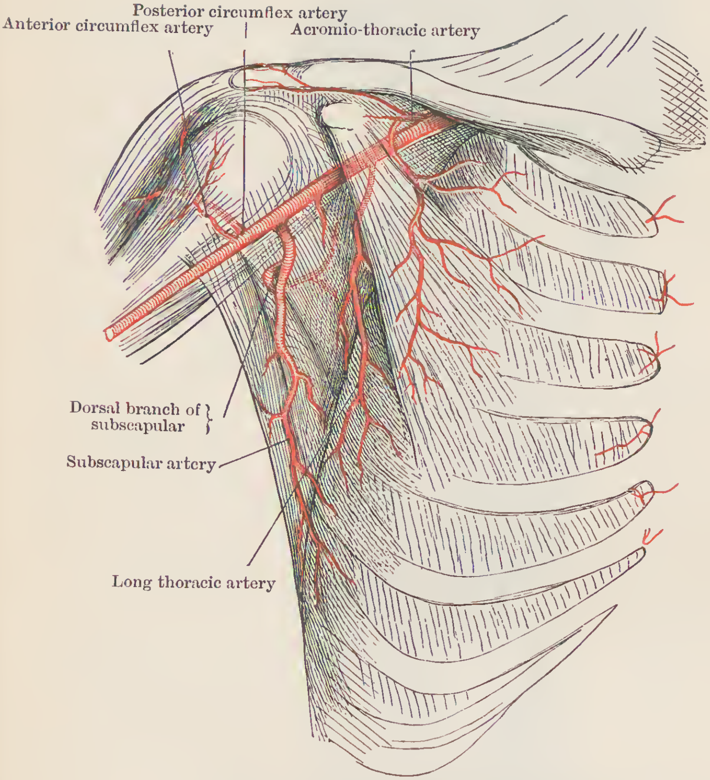


FIG. 329.—THE AXILLARY ARTERY. (C. Gegenbaur.)

To face p. 434.

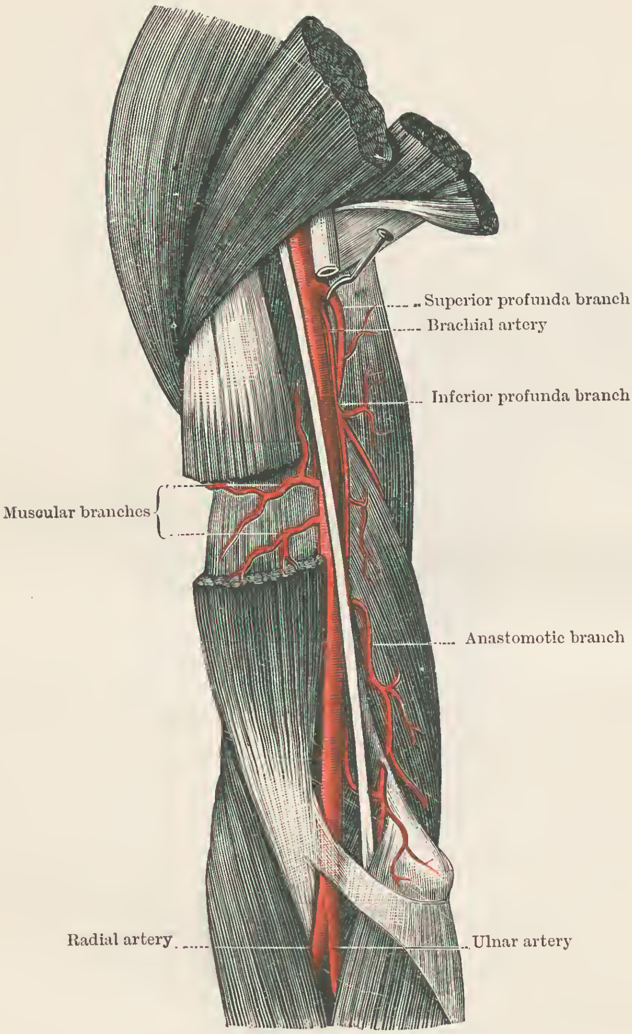


Fig. 330.—The Brachial Artery. (L. Testut.)

To face p. 435.

important are the acromio-thoracic, the long thoracic, the subscapular, and the posterior and anterior circumflex arteries.

(1) The **acromio-thoracic artery**, a short stem, arises from the front of the first part of the artery. Its branches, passing forwards, pierce the costo-coracoid membrane and supply the two pectoral muscles and the surrounding parts, and are divided, from their distribution, into four sets, the *thoracic*, *clavicular*, *acromial*, and *humeral*; one of the last named, a vessel of moderate size, descends for some distance between the deltoid and the pectoralis major, by the side of the cephalic vein.

(2) The **long thoracic** or **external mammary artery** arises from the second part of the main trunk, and is directed downwards and inwards along the lower border of the pectoralis minor muscle. Its branches supply the muscles of the anterior wall of the axilla, the mamma, and the axillary connective tissue and glands.

(3) The **subscapular artery**, usually the largest branch, arises from the third part of the axillary trunk, and is directed downwards and backwards, along the outer border of the scapula towards the lower angle; its branches ramify in the axilla, supply the muscles of the posterior wall, and take part in an anastomosis on both surfaces of the scapula with those of the suprascapular and posterior scapular arteries. The most important is the *dorsal branch*, which is usually larger than the continuation of the vessel. It arises near the commencement of the parent trunk, and is directed backwards through the triangular space bounded by the long head of the triceps, the teres major, and the margin of the scapula; it passes across the axillary border of the bone in a groove, and, under cover of the teres minor, gains the dorsum; some of its branches reach the lower angle.

(4) The **posterior circumflex artery**, a considerable branch, arises immediately below the subscapular artery, and is directed backwards, with the circumflex nerve, through the quadrilateral space bounded by the humerus, the long head of the triceps, and the teres muscles. Continuing its course it winds round the back of the humerus, and breaks up into numerous branches which supply the deltoid and teres muscles and the shoulder-joint, and anastomose with those of the anterior circumflex, acromio-thoracic, and superior profunda arteries.

(5) The **anterior circumflex artery**, a small vessel, arises a little below the posterior branch, and winds round the front of the humerus on the deep surface of the biceps and coraco-brachialis muscles; a slender branch runs upwards in the bicipital groove to the joint, and others ramify in the muscles and anastomose with the branches of the posterior circumflex artery.

Anastomoses of the branches of the axillary artery. The different branches anastomose very freely with one another and with the upper intercostal arteries. From above the suprascapular anastomoses with the acromio-thoracic, from below the superior profunda forms free connections

with the posterior circumflex. On both surfaces of the scapula the branches of the suprascapular, posterior scapular, and subscapular arteries anastomose freely with one another. The branches of the long thoracic which reach the mamma anastomose there with derivatives of the intercostal and internal mammary arteries.

Varieties of the axillary artery and its branches. In addition to the branches which have been described others are frequently met with; among these the *superior thoracic* running upwards and inwards from the first part, and the *alar thoracic* descending from the second part to supply the connective tissue and glands, may be specially mentioned. Occasionally (in the proportion of one in every ten cases) a large branch, continued into one of the arteries of the forearm, comes off the third part of the axillary trunk; this abnormality is one of the varieties of "high division" of the main artery of the limb. Frequently the dorsal branch of the subscapular artery comes off as a separate trunk, and, on the other hand, the subscapular and posterior circumflex often spring as a common vessel. The posterior circumflex is in many cases absent from the axillary altogether, its place being taken by a large branch which ascends behind the teres major muscle from the superior profunda of the brachial. The long thoracic artery is often double.

Surgical anatomy of the axillary artery. When the arm is hanging by the side the artery is bent with the convexity upwards, but when the limb is abducted to a position at right angles with the trunk the vessel holds a straight course, which may be marked by a line drawn from the middle of the clavicle to the inner border of the prominence of the coraco-brachialis and biceps muscles. The upper part of the artery is seldom interfered with by the surgeon, as the operation upon the third part of the subclavian is judged safer. In this portion of its course the vessel is deeply placed, and, along with the vein, is surrounded by a sheath continued downwards from the neck. The vein, when the arm is abducted, overlies the first part of the artery, and its walls are so closely connected with the costo-coracoid membrane that a wound is liable to lead to great bleeding, and to the further danger of entrance of air into the heart. The first part of the artery has sometimes been torn in cases of dislocation or fracture. The lower half of the third part of the artery is usually selected for ligature; the vessel here lies by the inner side of the coraco-brachialis, immediately under the deep fascia. An incision, about three inches in length, is made along the line of the artery; the inner margin of the coraco-brachialis is exposed, and the musculo-cutaneous and median nerves are drawn outwards, the internal cutaneous nerve is drawn inwards, and the hook passed from within outwards. The axillary vein is sometimes replaced in the lower part of the axilla by a continuation of the venae comites of the brachial; sometimes also an irregular band of muscular fibres from the latissimus dorsi crosses in front of the lower part of the artery. The current in the lower part of the artery may be

controlled by pressure directed outwards against the humerus. In opening an axillary abscess the surgeon should direct the point of the knife away from the axillary artery and avoid the subscapular behind, and the long thoracic in front, making his incision in the middle of the armpit.

The Brachial Artery.

The brachial or humeral artery (Fig. 330), the continuation of the axillary, extends from the lower margin of the teres major to the hollow in front of the elbow, where, opposite the neck of the radius, it divides into the radial and ulnar arteries. It lies immediately under the deep fascia, and is placed at first by the inner side of the humerus, and afterwards in front of the bone; close to its termination it sinks deeply between the pronator teres and supinator longus muscles. It rests behind successively upon the long head of the triceps, the inner head of the same muscle, the insertion of the coraco-brachialis, and the brachialis anticus; to its outer side lie the coraco-brachialis and, afterwards, the biceps, the latter muscle overlapping it in well developed subjects; in front it is crossed, near its termination, by the semilunar fascia from the biceps. Two venae comites, the inner being usually the larger, accompany it, and frequent though variable transverse branches, uniting them, cross in front of and behind the artery. The basilic vein, in the lower half of the arm, lies by its inner side, the deep fascia intervening; the median basilic vein crosses superficially at the bend of the elbow, the semilunar fascia being placed between it and the artery. The median nerve crosses in front of the artery, about the middle of the arm, being placed externally to it above, and internally to it below. The internal cutaneous nerve lies in contact with it internally, in the upper half of the arm; the ulnar nerve, in the same region, is internal and somewhat posterior to it; and the musculo-spiral nerve is behind it for a short distance at its upper end.

(1) A number of **muscular branches** are given off irregularly from the brachial trunk; the most important of them constitute a set of arteries which supply the biceps, and anastomose with one another.

(2) The **superior profunda artery**, the largest branch, springs from the inner side of the main trunk near its commencement, and passes downwards and backwards to reach the musculo-spiral groove, in which, accompanied by the musculo-spiral nerve, it winds round the back of the humerus. At the outer margin of the bone it divides into two branches, posterior and anterior; the *posterior* descends in the substance of the triceps muscle, behind the external intermuscular septum, and anastomoses below with the recurrent branch of the posterior interosseous artery; the *anterior* pierces the septum, along with the musculo-spiral nerve, and descends, under cover of the supinator longus, to anastomose with the recurrent branch of the radial artery. Numerous muscular branches to the triceps are detached by the superior profunda; a branch passes up-

wards to anastomose with the posterior circumflex of the axillary; and a slender nutrient artery enters a foramen on the back of the humerus.

(3) The **inferior profunda artery** arises from the brachial, a little above the middle of the arm, and descends behind the internal intermuscular septum, in company with the ulnar nerve, to the space between the internal epicondyle and the olecranon, where it anastomoses with the posterior recurrent branch of the ulnar and with the anastomotic artery.

(4) The **nutrient artery** of the humerus is variable in its origin, springing either directly from the main stem or from one of the branches. It is directed downwards and enters a canal near the insertion of the coraco-brachialis muscle.

(5) The **anastomotic artery** springs from the inner margin of the brachial, about two inches above the elbow. It anastomoses, under cover of the pronator teres muscle, with the anterior recurrent branch of the ulnar, and a branch pierces the internal intermuscular septum and winds round the back of the humerus, anastomosing with the posterior recurrent of the ulnar, the inferior profunda, and the superior profunda arteries.

Varieties of the brachial artery. Sometimes the brachial artery is found to deviate inwards from its usual course, passing, in company with the median nerve, round a supracondyloid process, and only regaining its normal position at the elbow; and even when no such process, or at best but a rudimentary bony elevation, is present, the vessel has been found with a considerable inward deflection, being bound down by fibres of the pronator teres or brachialis anticus. Frequently this variation in the course of the brachial artery co-exists with another abnormality, namely, the presence of another large arterial stem in the arm. The additional vessel springs from the axillary or from the upper part of the brachial, and descends along the usual line by the inner edge of the biceps to join the lower part of the brachial, or be continued into one of its main branches. It is in all probability derived from an enlargement of anastomotic connections between branches of the brachial ramifying in the biceps muscle and in the deep fascia, and similar branches of the main arteries of the forearm. At other times, even though the true brachial artery is not deflected from its usual course, it is reduced in calibre, and is accompanied, side by side, by an additional artery. In these circumstances the abnormal vessel is always placed in front of the median nerve, while the true brachial lies behind the nerve. The abnormal stem is variable in diameter; it may be of greater calibre than the true brachial, and may be continued below into one or more of the branches usually arising from the brachial artery. Further, it frequently happens that, when only one artery descends in the limb, occupying apparently the usual line, it is found in front of instead of behind the median nerve; in such a case it is probable that the true brachial has entirely disappeared, a more superficial stem replacing it.

The presence of more than one artery in the arm is frequent, the average being about one in every five cases. Sometimes, but rarely, the

brachial artery splits above into two trunks of equal size, uniting with one another below to form a single vessel, which divides in the usual manner into the radial and ulnar arteries. At other times, when there are two vessels, one is long and slender, springing from the brachial above and joining below either the brachial itself or one of its main divisions; such a slender vessel is called a *vas aberrans*. More frequently, when there are two arteries in the arm, they pass into the forearm as separate vessels, or at most are only connected with one another there by a slender transverse branch; the condition is known as *high division*, or high separation of one of the branches of the brachial artery. The student will understand, from what has been already said, that, of the two, the artery which has the proper relation to the median nerve is the true brachial, but, in the usual nomenclature of the different forms of high division, it is generally the larger of the two vessels which receives the name of brachial, the other being considered as a branch arising abnormally. In naming the different varieties, the interosseous artery of the forearm, in normal circumstances a branch from the upper part of the ulnar artery, is reckoned of equal importance with the ulnar and radial vessels. The most common variety is that which is termed a *high radial*, one of the stems being continued into the ulnar and interosseous, the other into the radial alone. Next in frequency comes the *high ulnar*, one stem being continued into the radial and interosseous, the other into the ulnar alone. Very rare is the *high interosseous*, one stem being continued into the radial and ulnar, the other into the interosseous alone. The point at which the high division takes place is most commonly in the upper part of the arm, frequently indeed in the axilla, less commonly in the lower part of the arm, and rarely in the middle.

The superior and inferior profunda arteries often spring by a common stem. Sometimes the superior profunda is absent, its place being taken by a branch from the posterior circumflex artery.

Surgical anatomy of the brachial artery. The course of the artery may be indicated by a line drawn from the axilla, a little behind the anterior fold, to the middle of the hollow in front of the elbow. The vessel may be compressed by pressure directed in the upper two-thirds of the course outwards and slightly backwards, in the lower third directly backwards. The artery may be ligatured at any point, the more usual places being the bend of the elbow and the middle of the arm. When the operation is performed at the elbow, an incision of about two inches in length is made along the inner edge of the biceps tendon. The median basilic vein is to be avoided, the semilunar fascia cut through, the venae comites separated, and the needle introduced from within outwards. When the operation is performed at the middle of the arm, the presence of the basilic vein in the superficial fascia is to be remembered. The arm is abducted and extended, and an incision about two and a half inches in length is made along the line of the artery. The inner edge of the biceps

must be defined, and with this object the limb is usually not supported from behind, as the pressure is apt to push forward the triceps muscle, which may confuse the operator. The median nerve here lies in front of the vessel, and is to be drawn outwards, and to aid this procedure the limb should be temporarily flexed; the needle is passed from the side on which the nerve lies, care being taken to avoid the venae comites. When the brachial artery is tied, the circulation is maintained chiefly through the anastomotic connections between the branches which ramify in the muscles and in the fascia.

The Ulnar Artery.

The ulnar artery (Figs. 331–335) is the larger of the two vessels into which the brachial divides. It is directed downwards through the forearm, at first with a slight arch inwards, and afterwards almost vertically, then crosses in front of the anterior annular ligament, by the outer side of the pisiform bone and the inner side of the unciform process, to end in the superficial palmar arch. It is at first deeply placed, and passes behind the superficial muscles from the internal epicondyle; further down it is comparatively superficial, being only overlapped by the edge of the flexor carpi ulnaris; at the lower end of the forearm it is uncovered by the muscle, lying by the outer edge of its tendon under the deep fascia; at the wrist it is crossed by some fibres from the tendon of the flexor carpi ulnaris. It rests behind at first upon the tendon of the brachialis anticus, afterwards upon the flexor digitorum profundus, and finally upon the anterior annular ligament. Two venae comites accompany it. The median nerve crosses it superficially close to its origin, the deep head of the pronator teres intervening. The ulnar nerve lies by its inner side in the lower half of the forearm and at the wrist.

Of the branches given off in the forearm the most important is the interosseous artery; in the upper part two recurrent branches are detached, and in the lower part two carpal branches are given off; in addition there are numerous muscular branches. At the lower border of the anterior annular ligament the ulnar detaches a deep branch which completes the deep palmar arch of the hand.

(1) The **recurrent branches.** The *anterior recurrent artery,* a small vessel, passes upwards under cover of the pronator teres to anastomose with the anastomotic branch of the brachial. The *posterior recurrent artery*, a little larger than the anterior, arises along with it, or immediately below it, and passes upwards between the heads of the flexor carpi ulnaris to anastomose with the inferior profunda and anastomotic arteries.

(2) The **interosseous artery**, a short stem of considerable thickness, arises from the ulnar about an inch from its commencement, and passes backwards and downwards to the upper margin of the interosseous membrane, where it divides into anterior and posterior branches. The

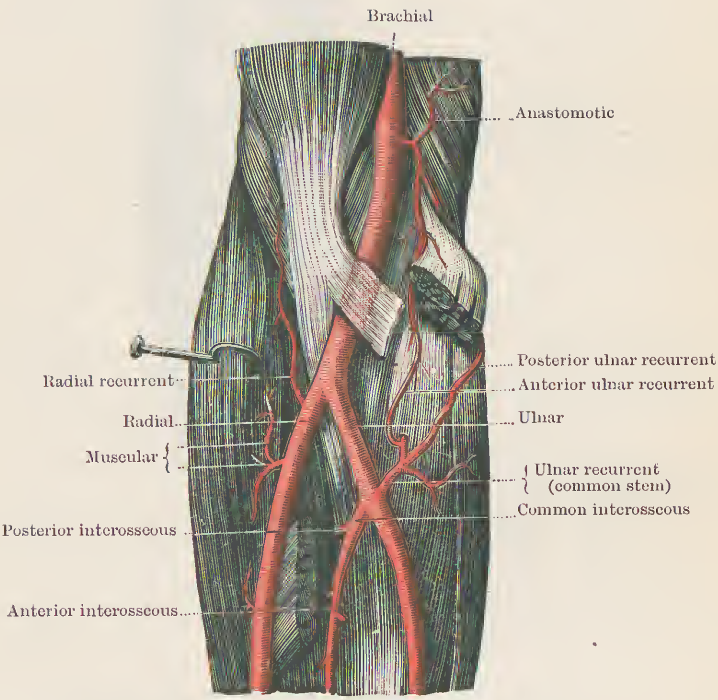


Fig. 331.—The Division of the Brachial Artery. (L. Testut.)

To face p. 440.

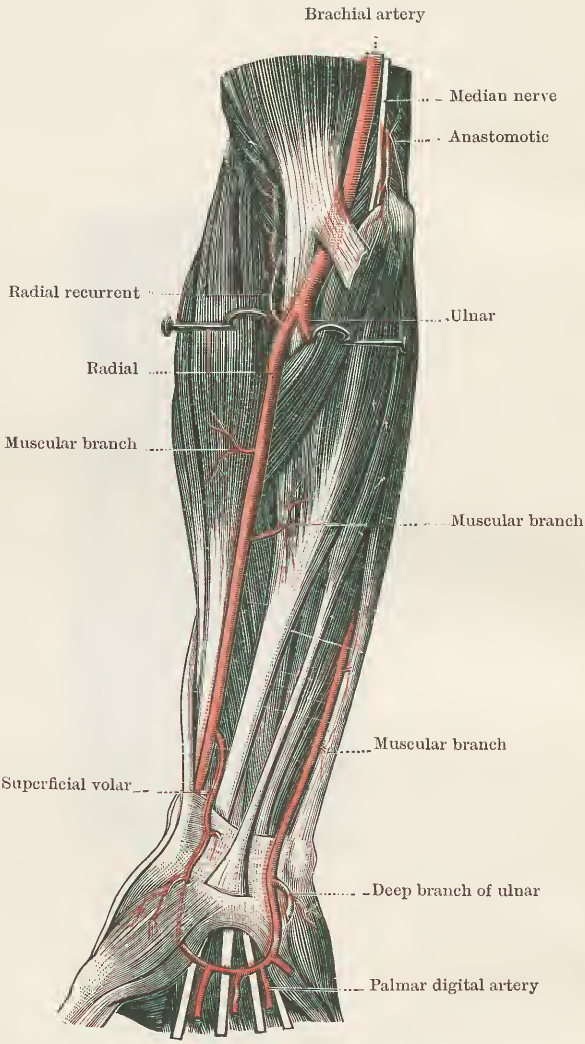


FIG. 332.—THE ARTERIES OF THE FOREARM, superficial dissection. (L. Testut.)

To face p. 441.

anterior interosseous branch descends in front of the interosseous membrane, in company with a branch of the median nerve, as far as the upper border of the pronator quadratus muscle; it then pierces the membrane and is continued to the back of the wrist, where it terminates in anastomosis with the posterior carpal vessels. On its way it gives off, in addition to a number of muscular branches—(*a*) a slender *median artery* which accompanies the median nerve in the forearm, and is sometimes much enlarged to take part in the supply of the hand; (*b*) nutrient arteries to the radius and ulna; (*c*) anterior communicating branches which, in front of the wrist, anastomose with the anterior carpal arteries. The **posterior interosseous branch** passes backwards over the upper part of the interosseous membrane, and descends between the superficial and deep layers of the posterior muscles; much reduced in size below, it terminates in anastomosis with the arteries on the back of the wrist. Besides numerous muscular branches, it gives off a *recurrent branch* which passes upwards, under cover of the anconeus, to anastomose with the posterior terminal division of the superior profunda artery.

(3) The **carpal branches**. The *posterior carpal artery* is given off a little above the pisiform bone, and passes backwards under cover of the tendon of the flexor carpi ulnaris; it detaches *a dorsal digital branch for the ulnar side of the little finger*, and inosculates on the back of the wrist with the posterior carpal branch of the radial to form the posterior carpal arch. The *anterior carpal artery* is a very slender twig which reaches the front of the carpus and assists to form the anterior carpal arch.

(4) The **deep branch** is given off at the lower border of the anterior annular ligament. It passes backwards between the abductor and flexor minimi digiti brevis to inosculate with the deep palmar arch.

Varieties of the ulnar artery. High origin of the ulnar is said to occur in one in thirteen cases; when it takes place the vessel, instead of passing behind the muscles from the inner epicondyle, generally takes a superficial course and only gains its normal situation in the lower fourth of the forearm. In such cases the recurrent and interosseous branches spring from one of the two trunks into which the other artery in the arm divides. An *enlarged median artery* may spring from the anterior interosseous or directly from the ulnar. It generally joins the superficial palmar arch, and, in entering the hand, may pass in front of or behind the anterior annular ligament.

The Radial Artery.

The radial artery (Figs. 331-335), continuing the line of the brachial, passes almost directly downwards as far as the lower end of the radius; it then bends backwards and downwards to reach the back of the wrist, and finally enters the palm between the first and second metacarpal bones and is continued into the deep palmar arch. *In the forearm* it lies at first in the

hollow of the elbow, separated by some fatty tissue from the supinator brevis; afterwards it rests in succession upon the insertion of the pronator teres, the radial slip of the flexor sublimis, the flexor pollicis longus, the pronator quadratus, and the lower end of the radius. The supinator longus is external to it, overlapping it in the upper half of the forearm; to its inner side lie the pronator teres, and, lower down, the flexor carpi radialis; the radial nerve is in contact with it externally in the middle third of the forearm.

At the wrist it first bends backwards below the styloid process, resting upon the external lateral ligament, and afterwards descends upon the back of the scaphoid and trapezium to the interval between the heads of the first and second metacarpal bones; in this part of its course it is crossed superficially, first by the tendons of the extensors of the metacarpal bone and first phalanx of the thumb, and afterwards by that of the second phalanx of the thumb. As it passes forwards into the hand it is placed between the heads of the first dorsal interosseous muscle.

In the palm the radial artery turns inwards under cover of the short flexor muscle of the thumb, and is continued into the deep palmar arch. Two venae comites accompany the radial artery in its whole course.

In the forearm, in addition to numerous muscular branches, the radial detaches a recurrent branch, an anterior carpal branch, and the superficial volar branch. At the wrist it gives off a posterior carpal branch, the first dorsal interosseous, the dorsalis indicis, and the dorsalis pollicis arteries. In the palm, before passing into the deep arch, it gives off the arteria princeps pollicis and the radialis indicis.

(1) The **recurrent branch** passes upwards under cover of the supinator longus to anastomose with the anterior division of the superior profunda artery.

(2) The **anterior carpal artery**, a very slender vessel, arising near the wrist, reaches the front of the carpus and takes part, along with the anterior carpal branch of the ulnar, in forming the anterior carpal arch. The *anterior carpal arch* is of small size, and distributes minute branches which supply the carpal bones and anastomose with offsets from the anterior interosseous artery of the forearm and from the deep palmar arch.

(3) The **superficial volar artery**, of very variable size, arising near the wrist, passes among the short muscles of the thumb, and, when well developed, inosculates with the termination of the superficial palmar arch.

(4) The **posterior carpal branch** takes origin under cover of the extensor tendons of the thumb, and runs inwards upon the back of the carpus to anastomose with the posterior carpal branch of the ulnar. The **posterior carpal arch**, formed by the inosculation of the two posterior carpal arteries, is of small size. It gives off—(*a*) *recurrent branches* which ramify upon the carpus and anastomose with the terminal twigs of the anterior and posterior interosseous arteries of the forearm; and (*b*) the *dorsal interosseous arteries of the two inner spaces.*

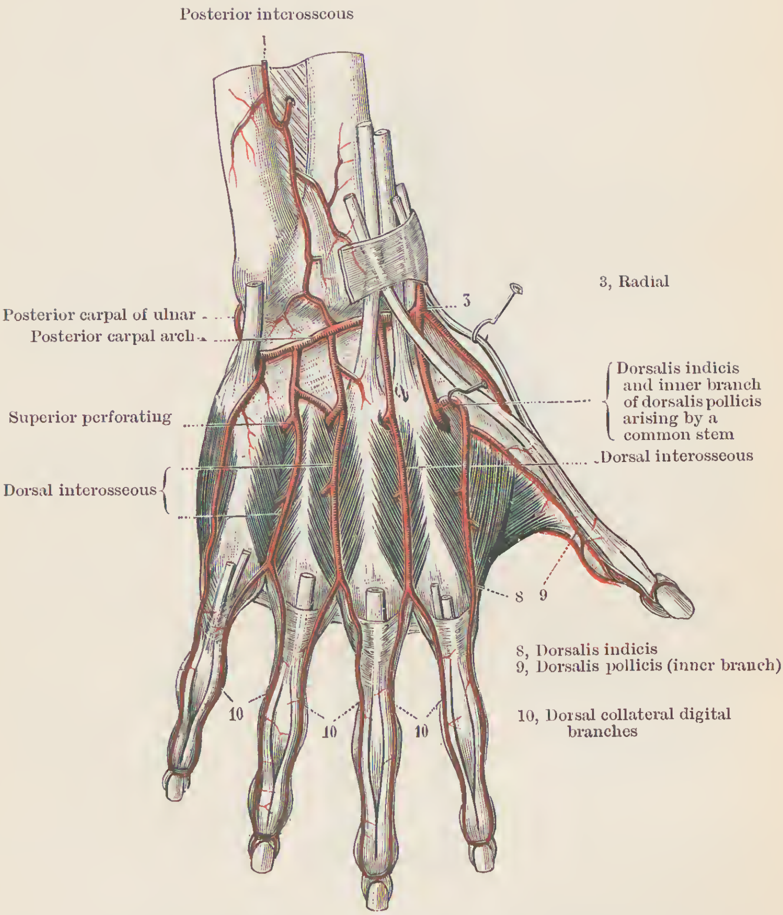


FIG. 333.—ARTERIES OF THE BACK OF THE HAND. (L. Testut.)

To face p. 442.

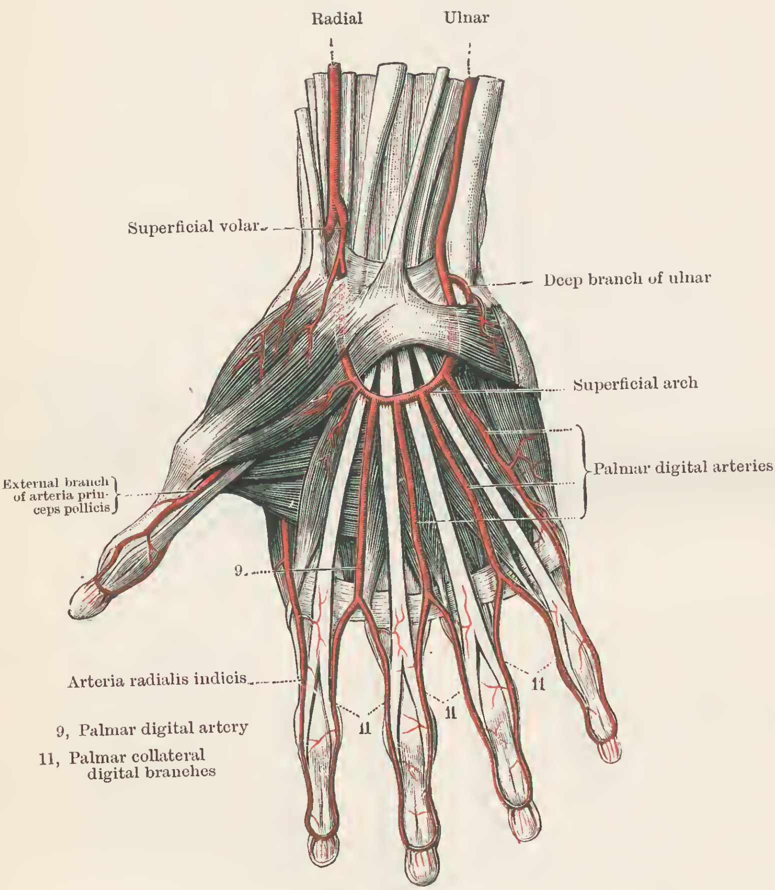


FIG. 334.—THE SUPERFICIAL PALMAR ARCH. (L. Testut.)

To face p. 443.

(5) The **first dorsal interosseous artery** springs from the radial as it descends on the back of the carpus.

The three *dorsal interosseous arteries* descend, one in each of the three inner intermetacarpal spaces; they lie upon the dorsal interosseous muscles, on the deep surface of the extensor tendons. Each artery gives off—(*a*) at the upper extremity of its space a *superior perforating branch* which joins the deep palmar arch, and (*b*) at the lower extremity of the space an *inferior perforating branch* which joins the palmar digital artery from the superficial palmar arch. At the digital cleft each vessel divides into two *dorsal collateral branches* which descend upon the contiguous sides of the fingers and anastomose, about the level of the base of the second phalanx, with the dorsal branches of the palmar collateral arteries.

(6) The **dorsalis indicis artery** springs from the radial before it passes between the heads of the first interosseous muscle. It descends upon the radial border of the index finger.

(7) The **dorsalis pollicis artery** arises in close proximity to the last mentioned branch and, after descending upon the back of the metacarpal bone of the thumb, divides into outer and inner branches. Frequently the outer and inner branches for the thumb rise separately from the radial artery.

(8) The **arteria princeps pollicis** passes downwards upon the anterior surface of the metacarpal bone of the thumb, and in the interval between the insertions of the two portions of the flexor pollicis brevis muscle divides into two branches which anastomose and pulsate on the front of the second phalanx of the thumb.

(9) The **arteria radialis indicis** passes downwards under cover of the adductor pollicis and runs along the radial side of the index finger.

Varieties of the radial artery. High origin is said to occur about once in eight cases; an origin below the usual point is comparatively rare. The vessel seldom deviates from its usual course through the forearm, but it is sometimes much reduced in size, and its entire absence has been recorded. Its recurrent branch may be reduced in size, or transferred altogether to the ulnar or interosseous stem, or, on the other hand, it may be much enlarged. The branches which are distributed to the hand are very variable in size.

The anastomoses around the elbow-joint. The arteries from above are the *anterior* and *posterior divisions* of the *superior profunda*, the *inferior profunda*, and the *anastomotic;* those from below are the *radial recurrent*, the *posterior interosseous recurrent*, and the *posterior* and *anterior ulnar recurrents.* The anastomotic, besides anastomosing with the anterior ulnar recurrent, pierces the internal intermuscular septum, forms connections with the inferior profunda and posterior ulnar recurrent, and sends a branch over the olecranon fossa to anastomose with the posterior branch of the superior profunda.

Surgical anatomy of the arteries of the forearm. The radial and ulnar arteries are seldom ligatured except in cases of wound. The course of the radial artery in the forearm may be marked by a line drawn from the middle of the hollow of the elbow to the anterior border of the tendon of the extensor ossis metacarpi pollicis at the wrist. The vessel may be tied in any portion of this course, but the operation is most easily performed in the lower third of the forearm, where the artery lies between the tendons of the supinator longus and flexor carpi radialis. The position of the ulnar artery in the lower half of the forearm may be marked on the surface by the lower part of a line drawn from the internal epicondyle to the outer side of the pisiform bone. Above the wrist the artery lies by the radial side of the tendon of the flexor carpi ulnaris. The operation is only performed in the lower part of the forearm.

The Superficial Palmar Arch.

The superficial palmar arch (Fig. 334), the continuation of the ulnar artery, turns outwards, forming a bend with the convexity reaching downwards as far as the line between the upper and middle thirds of the palm. It passes behind the palmaris brevis and the palmar aponeurosis, and rests upon the short muscles of the little finger, the digital branches of the median nerve, and the tendons of the superficial flexor of the fingers. It terminates, much reduced in size, opposite the metacarpal bone of the index finger, by inosculating with either the superficial volar artery or the arteria radialis indicis. It is accompanied by two small venae comites. In addition to a number of small superficial branches, it gives off the palmar digital arteries which supply the three inner fingers and the ulnar side of the index finger.

The **digital arteries** are four in number. The first descends to run along the ulnar border of the little finger. The other three descend, one in each of the three inner intermetacarpal spaces; each artery lies, between the flexor tendons, in front of the nerve and the lumbricalis muscle, and divides, about a fourth of an inch behind the cleft, into two branches, the collateral digitals, which run along the contiguous sides of the fingers. Immediately before dividing, each of the three arteries is joined by a palmar interosseous branch from the deep palmar arch, and by an inferior perforating branch from the dorsal interosseous artery of its space. Each *collateral branch* descends upon the side of a finger between the palmar and dorsal nerves, and terminates, in anastomosis with its fellow, in front of the third phalanx; it supplies both surfaces of the finger, and its dorsal branches anastomose about the base of the second phalanx with the dorsal digital artery.

The Deep Palmar Arch.

The deep arch (Fig. 335), the continuation of the radial artery, is completed internally by inosculation with the deep branch of the ulnar artery. It is placed about half an inch nearer the wrist than the superficial arch and lies upon the bases of the metacarpal bones, behind the flexor tendons; it gives off three palmar interosseous arteries, and some small recurrent vessels, and receives the superior perforating arteries.

The **palmar interosseous arteries**, three in number, descend, one in each of the three inner interspaces, to join, near the clefts of the fingers, the digital branches of the superficial arch. The *recurrent branches*, small and irregular, pass backwards from the deep arch to anastomose with the anterior carpal arteries. The superior perforating arteries may join the palmar interosseous arteries instead of the deep arch.

Varieties of the arteries of the hand. Very frequently the arrangement of the branches of the chief arterial arches departs from the normal type; but as the connections between the different sets of vessels are so free, deficiency in one arch is made up for by excess in another. The deep arch may largely take the place of the superficial, or the superficial may supply the digital vessels to the index finger and thumb. An enlarged superficial volar or a median artery may assist or take the place of the ulnar in the hand, and by an increase in the size of perforating branches defective interosseous vessels may be compensated for.

THE DESCENDING THORACIC AORTA.

The descending portion of the thoracic aorta (Fig. 317) passes downwards in the posterior mediastinal space from the left side of the fourth dorsal vertebra, gradually inclining towards the middle line, and pierces the diaphragm opposite the twelfth dorsal vertebra. It rests closely upon the vertebral column, and lies behind the pericardium above and the vertebral portion of the diaphragm below. At its commencement it is crossed in front by the root of the left lung, and the pleura is in contact with it on the left side. The oesophagus lies at first by its right side, lower down it is directly in front of the aorta, and still lower it is placed somewhat to the left. The thoracic duct and the larger azygos vein lie by its right side; the smaller azygos vein ascends by its left side as far as the seventh dorsal vertebra, where it passes to the right behind it.

It detaches numerous small offsets to the pericardium, the oesophagus, the diaphragm, and the glands of the posterior mediastinum; its more important branches are the bronchial and intercostal arteries.

The **bronchial arteries** supply the bronchi, the lungs, and the bronchial glands. They are variable in number and in their mode of origin. The *right bronchial artery*, usually single, arises in some cases from the first aortic intercostal of the right side, in others from the aorta, by a common

stem, with the upper of the two bronchial arteries of the left side. The *left bronchial arteries,* generally two in number, spring from the upper part of the aortic trunk. The arteries pass outwards in the roots of the lungs behind the bronchi, and ramify with the air tubes.

The **intercostal arteries** are usually nine in number on each side, the first two spaces being supplied by the superior intercostal branch of the subclavian artery. They spring from the posterior part of the aorta, and pass outwards crossing the vertebral bodies, the first two or three with an inclination upwards, the others almost transversely. On account of the position of the parent trunk the higher branches of the right side are longer than the corresponding vessels of the left. In crossing the vertebral bodies the arteries of the right side pass behind the greater azygos vein and the thoracic duct, those of the left behind the smaller azygos veins, or the left superior intercostal vein. Opposite the necks of the ribs the vessels of each side are crossed in front by the gangliated cord of the sympathetic. At the posterior extremities of the spaces they lie upon the external intercostal muscles, and are covered in front by the pleura, but further forwards they pass behind the internal intercostals, and afterwards continue their course between the two muscular layers. In each space the artery runs in the subcostal groove, along the lower margin of the upper of the two ribs, its companion vein lying above it, and the intercostal nerve below: near the anterior extremity it terminates in anastomosis with an anterior intercostal branch of the internal mammary, the musculo-phrenic, or the superior epigastric, according to the region. In addition to numerous small offsets, the intercostal arteries detach dorsal, collateral, and lateral branches. The successive intercostal arteries anastomose with one another by slender vessels which form two chains, one in front of the rib necks, the other between the rib necks and the transverse processes; in addition, the dorsal branches are connected with one another by slender twigs which lie behind the transverse processes. The first artery anastomoses with the superior intercostal branch of the subclavian.

The *dorsal branch* passes backwards between the transverse processes, by the inner edge of the superior costo-transverse ligament. It detaches offsets to the spinal canal (see p. 429), and afterwards divides among the muscles of the back into two vessels, internal and external in position, which accompany the branches of the posterior primary division of the corresponding spinal nerve. The *collateral branch* arises in the intercostal space, in the neighbourhood of the angles of the ribs. It descends at first, crossing the space obliquely, and afterwards runs forwards between the muscular layers, along the upper margin of the lower of the two ribs. It terminates like the parent trunk in anastomosis with an anterior intercostal branch of the internal mammary or musculo-phrenic. The *lateral branch* passes outwards along with the lateral branch of the intercostal nerve of the space, supplying the muscles and the skin. Besides the branches specially described, the intercostal arteries give off a number of

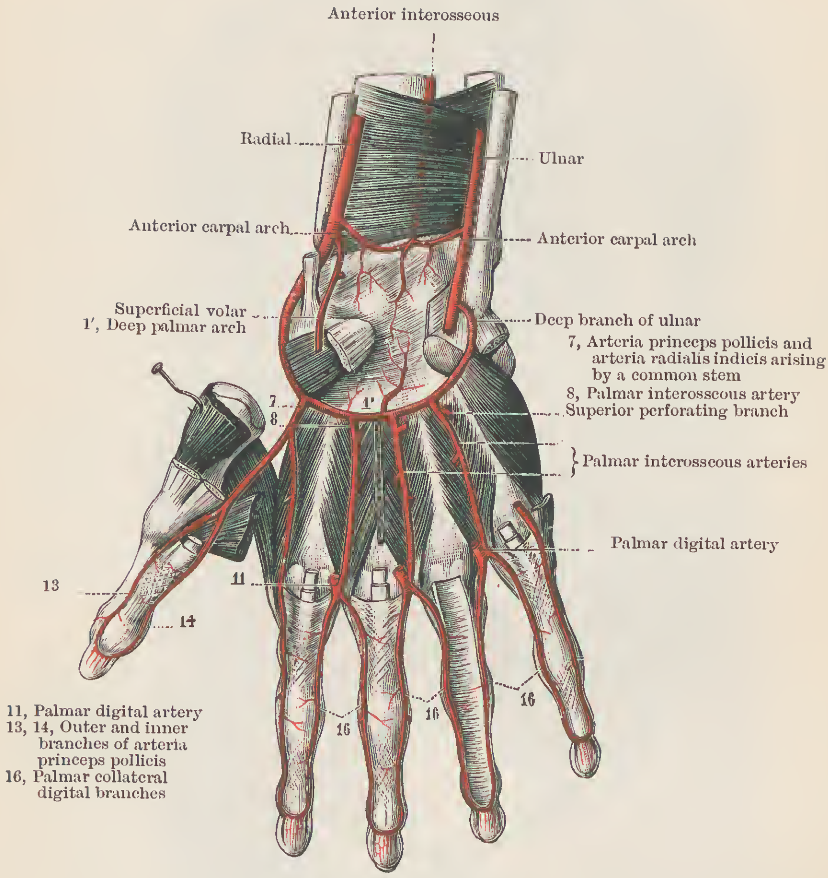


FIG. 335.—THE DEEP ARTERIES OF THE PALM. (L. Testut.)

To face p. 446.

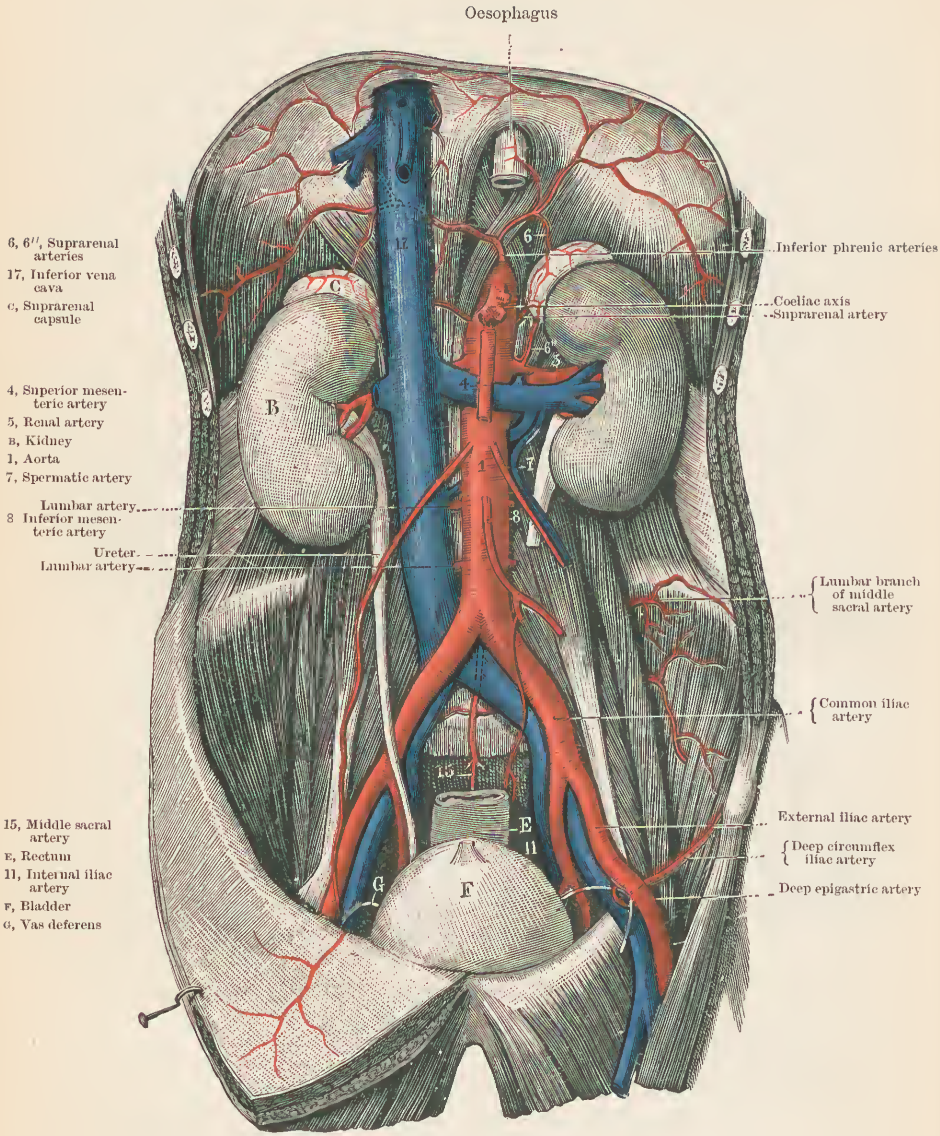


FIG. 336.—ABDOMINAL AORTA. (L. Testut.)

To face p. 447.

small twigs which supply the vertebral bodies, the pleura, the ribs, and the intercostal muscles; some of the latter enter the mammary gland and during lactation may increase to a considerable size.

THE ABDOMINAL AORTA.

The abdominal aorta (Figs. 336, 337) descends upon the front of the column, from the opening in the diaphragm, opposite the twelfth dorsal vertebra, to the middle of the body of the fourth lumbar vertebra, where, a little to the left of the middle line, it terminates by dividing into the common iliac arteries. The place of division is on a level with a line drawn across the abdominal wall between the highest points of the iliac crests. The vessel is placed at first between the crura of the diaphragm, and between it and the right crus the greater azygos vein and the thoracic duct are interposed. The inferior vena cava lies in contact with its right side below, but higher up is separated from it by the crus. The left lumbar veins pass behind it. Its anterior surface is successively in contact with the solar plexus, the splenic vein and pancreas, the left renal vein, the third part of the duodenum, and the aortic plexuses and the peritoneum; a number of lymphatic glands surround and overlie it. Its branches, which are numerous and large, are divided into two groups, parietal and visceral.

The parietal branches are the inferior phrenic, the lumbar, and the middle sacral. The visceral branches are the coeliac axis, the superior mesenteric, the inferior mesenteric, the suprarenal, the renal, and the spermatic or ovarian.

Parietal Branches of the Abdominal Aorta.

The **inferior phrenic arteries** ramify on the under surface of the diaphragm. They spring either by a common stem, or separately, from the front of the aorta immediately after it has entered the abdomen. Each artery inclines upwards and outwards on the corresponding crus, the vessel of the right side passing behind the vena cava, that of the left behind the oesophagus. At the posterior margin of the central leaflet of the trefoil tendon each artery divides into an anterior and posterior branch. The *anterior branch* passes forwards to anastomose with the branches of the internal mammary artery, and with its fellow of the opposite side; *the posterior branch* passes outwards and enters into anastomosis with the lower intercostal arteries. In addition to the terminal branches, each artery supplies a small branch to the suprarenal capsule, the *superior suprarenal.* The artery of the right side supplies offsets to the vena cava, that of the left side gives twigs to the oesophagus. Occasionally there is but one inferior phrenic artery, and sometimes one or both vessels arise from the coeliac axis.

The **lumbar arteries** are comparable in their distribution to the inter-

costal vessels. They are usually five in number on each side. The first passes outwards upon the body of the last dorsal vertebra, the others, in succession, upon the bodies of the first four lumbar vertebrae. The first and second pass behind the crura of the diaphragm, and those of the right side cross behind the vena cava. They pass behind the sympathetic nerve trunk and the psoas muscle, and the first artery, which accompanies the last dorsal nerve, usually crosses in front of the quadratus lumborum, while the others as a rule pass behind that muscle. In the abdominal wall they course at first between the transversalis and internal oblique muscles, and finally enter the sheath of the rectus. They give off dorsal, lateral, and terminal branches which are similar in their distribution to the corresponding offsets of the intercostal arteries. They form anastomotic connections with one another, with the lower intercostal arteries, the circumflex iliac, middle sacral, and ilio-lumbar arteries, and by their terminal branches with the superior and deep epigastric arteries.

The **middle sacral artery** arises from the back of the aorta about a fourth of an inch above its bifurcation, and is continued downwards in front of the last lumbar vertebra and the sacrum to the coccygeal gland, in which, much reduced in size, it terminates. It gives off on each side—(1) a *lowest lumbar artery*, which is sometimes of considerable size, and runs outwards upon the body of the fifth lumbar vertebra; (2) *lateral branches*, which ramify upon the front of the sacrum. In front it detaches some *anterior branches*, which enter the mesorectum. The middle sacral artery represents the sacral portion of the aorta of the lower animals.

Visceral Branches of the Abdominal Aorta.

The **coeliac axis** (Fig. 338), a very short trunk, springs from the front of the aorta, immediately above the pancreas. It is about a third of an inch in length, and divides at its extremity into the hepatic, gastric, and splenic arteries. The solar plexus surrounds it at its origin, and the semilunar ganglia are placed by its sides.

(*a*) The **hepatic artery** passes at first forwards and to the right, along the upper border of the pancreas as far as the upper margin of the first part of the duodenum. It then turns upwards in front of the foramen of Winslow, between the layers of the small omentum, in company with the common bile duct, which lies by its right side, and the portal vein which lies behind it. Close to the liver it divides into right and left terminal branches. On its way it gives off—(1) two or three small *pancreatic branches*; (2) as it is entering the small omentum, the *pyloric artery* which descends to the neighbourhood of the pylorus, and runs from right to left along the small curvature of the stomach, inosculating with the gastric artery; (3) immediately above the pyloric, the *gastro-duodenal artery* which descends behind the first part of the duodenum and divides into two branches; one of these, the *right gastro-epiploic*, courses along the greater curvature

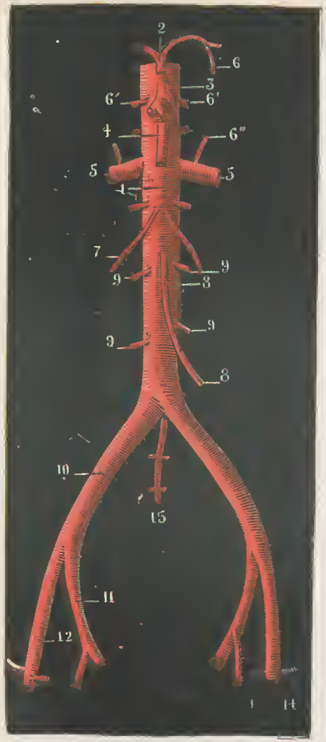


FIG. 337.—DIAGRAM OF THE BRANCHES OF THE ABDOMINAL AORTA. 1, Aorta; 2, inferior phrenic; 3, coeliac axis; 4, superior mesenteric; 5, renal; 6, 6′, 6″, suprarenal; 7, spermatic; 8, inferior mesenteric; 9, lumbar; 10, common iliac; 11, internal iliac; 12, external iliac; 15, middle sacral. (L. Testut.)

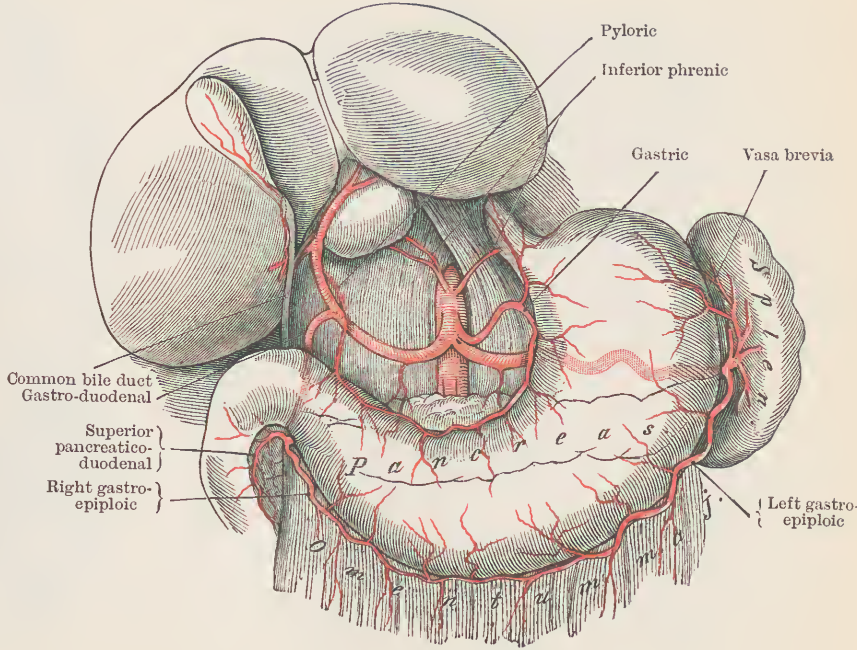


FIG. 338.—THE COELIAC AXIS AND ITS BRANCHES. (C. Gegenbaur.)

To face p. 448.

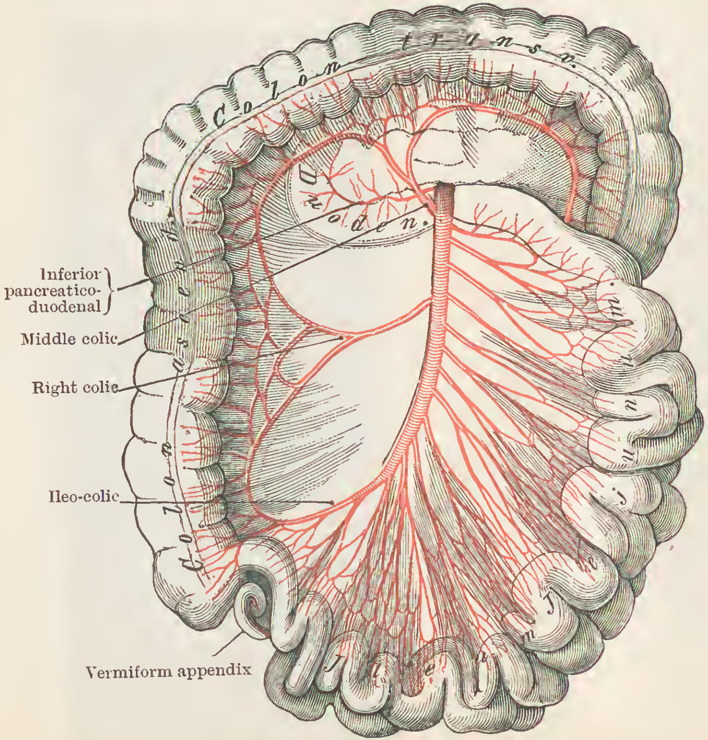


Fig. 339.—The Superior Mesenteric Artery and its Branches. (C. Gegenbaur.)

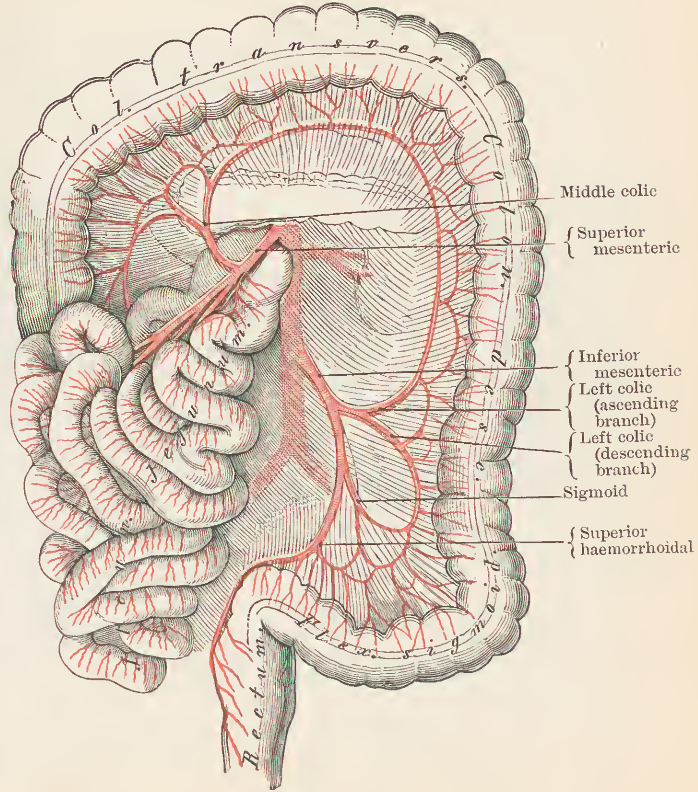


Fig. 340.—The Mesenteric Arteries. (C. Gegenbaur.)

To face p. 449

of the stomach from right to left between the layers of the great omentum, supplying both gastric and omental branches, and terminates by anastomosing with the left gastro-epiploic branch from the splenic artery; the other, the *superior pancreatico-duodenal artery*, descends between the head of the pancreas and the duodenum, supplying both, and anastomoses with the inferior pancreatico-duodenal branch from the superior mesenteric artery. The *right terminal branch* of the hepatic artery passes behind or between the hepatic and cystic ducts, and after giving off the *cystic branch* to the gall bladder reaches the right end of the portal fissure, where it divides into a number of branches which supply the greater part of the right lobe. The *left terminal branch* passes towards the left end of the transverse fissure to enter the left lobe, which it supplies. It gives off in addition a branch to the Spigelian lobe, and it partly supplies the quadrate lobe.

The hepatic artery may spring directly from the aorta. One or other of the terminal divisions is sometimes assisted or replaced by branches of the superior mesenteric or of the gastric. The whole artery may be wanting, its place being taken by branches from one or both of the above-mentioned trunks.

(*b*) The **gastric artery** (*coronary artery of the stomach*) (Fig. 338), the smallest branch of the coeliac axis, runs at first upwards and to the left behind the posterior wall of the lesser sac of the peritoneum to the cardiac end of the stomach, where it detaches some oesophageal branches. It then bends sharply downwards and to the right, and courses along the lesser curvature of the stomach towards the pylorus. It terminates by inosculating with the pyloric branch of the hepatic artery. Its chief branches are *oesophageal* and *gastric*; the former anastomose with the thoracic oesophageal arteries; the latter descend on both surfaces of the stomach, and anastomose with the branches of the arteries of the greater curvature. A small *hepatic branch* passes to the left lobe of the liver and anastomoses with the left branch of the hepatic artery; occasionally this branch is much enlarged, and it may assist or even replace the left hepatic artery.

(*c*) The **splenic artery** (Fig. 338), the largest branch of the coeliac axis, passes to the left and courses, often in a tortuous manner, along the upper border of the pancreas and across the anterior surface of the left kidney. It lies behind the posterior wall of the smaller sac of the peritoneum, and approaches the spleen between the layers of the splenio-phrenic ligament. It supplies branches to the pancreas, spleen, and stomach. The *pancreatic branches* are small and numerous; one of them larger than the others runs from left to right in the gland along with the duct. The *left gastro-epiploic artery* arises near the termination of the parent trunk, and passes from left to right along the greater curvature of the stomach; it terminates by inosculating with the right gastro-epiploic branch of the hepatic artery; its branches, gastric and omental, in their distribution anastomose with offsets of the other gastric and the colic arteries. The *vasa brevia* of the

stomach, four or five in number, pass between the layers of the gastro-splenic omentum to the left extremity of the stomach, and anastomose with the other gastric arteries. The *splenic branches*, six or seven in number, enter the hilum of the spleen.

The **superior mesenteric artery** (Fig. 339), a little smaller than the coeliac axis, arises below it from the front of the aorta, under cover of the pancreas. It emerges between the pancreas and duodenum and, entering the mesentery, passes between its folds downwards and to the right towards the caecum. Its branches supply the lower part of the duodenum, the rest of the small intestine, the ascending colon, and half of the transverse colon. The *inferior pancreatico-duodenal* branch springs from the right side of the parent trunk and, after passing to the right, ascends between the pancreas and duodenum to anastomose with the superior pancreatico-duodenal branch of the gastro-duodenal of the hepatic artery. The *middle colic* artery springs from the right side of the parent trunk and passes forwards in the meso-colon to supply the right half of the transverse colon. It inosculates with the ascending branch of the left colic of the inferior mesenteric artery. The *right colic*, arising from the right side of the main vessel, passes outwards to the ascending colon. The *ileo-colic*, also springing from the right side, passes downwards and to the right and supplies the caecum and the neighbouring portions of the tube. The *small intestinal branches* (*vasa intestini tenuis*), twelve to sixteen in number, pass from the front of the parent stem to the small intestine. The successive branches of the superior mesenteric artery inosculate with one another, forming loops, the branches from which, again inosculating, form secondary loops; and between the arteries which pass to the jejunum and ileum, tertiary and even quaternary loops may thus be formed. From the ultimate loops branches pass to both sides of the intestine, communicating in the wall freely with one another.

Variations in the superior mesenteric artery are by no means uncommon. The number of branches is often reduced by the conjunction, at their bases, of neighbouring colic arteries; on the other hand, additional branches are frequently detached to viscera other than those usually supplied by the vessel.

The **inferior mesenteric artery** (Fig. 340), smaller than the superior, arises from the front of the aorta about an inch and a half above the bifurcation. It descends with an inclination to the left, giving off the left colic and sigmoid branches, and is continued as the superior haemorrhoidal artery into the pelvis, crossing in its course the left common iliac artery. The *left colic* branch passes to the left and divides into an ascending and descending branch, the former of which anastomoses with the middle colic artery, the latter with the sigmoid artery. The *sigmoid* branch runs downwards and to the left and breaks up for the supply of the sigmoid flexure; it anastomoses below with the superior haemorrhoidal artery. The branches of the left colic and sigmoid arteries form

loops similar to those which are formed by the branches of the other colic arteries. The *superior haemorrhoidal artery* courses between the layers of the mesorectum and divides into two branches which descend, one on each side of the rectum. Four or five inches from the anus these branches pierce the muscular coat and break up into a number of slender descending vessels which reach as far as the internal sphincter and anastomose with one another and with branches of the middle haemorrhoidal arteries from the internal iliac stems.

The **suprarenal arteries** (*capsular arteries* or *middle suprarenal arteries*) (Fig. 336) are two slender vessels which arise from the aorta about the level of the place of origin of the coeliac axis. Each passes outwards across the crus of the diaphragm to the suprarenal capsule of its own side. Each capsule receives in addition a superior artery from the inferior phrenic and an inferior branch from the renal artery.

The **renal arteries** (Fig. 336), vessels of considerable size, spring from the aorta a little below the place of origin of the superior mesenteric artery and pass outwards, one on each side, to the kidney. The right vessel is a little lower in position and is also slightly longer than the left; on its way outwards it passes behind the inferior vena cava. Both arteries lie behind their companion veins, and their four or five terminal branches at the hilum of the kidney are placed in front of the pelvis of the ureter. Besides the terminal branches each artery furnishes a small *inferior capsular artery* to the suprarenal capsule, and some twigs to the ureter and to the glands and connective tissue which lie around the kidney.

Variations in the renal arteries are very common. Accessory renal arteries are often present, in rare cases reaching in number five or six. The terminal branches which in normal circumstances pass in at the hilum may enter the kidney at any spot.

The **spermatic arteries** (Fig. 336), of the male, spring close together from the front of the aorta a little below the place of origin of the renal arteries. Each artery descends with an outward inclination, crossing the ureter and the distal extremity of the external iliac artery, and at the deep abdominal ring enters the inguinal canal in company with the vas deferens, in front of which it descends in a somewhat tortuous manner to the testicle. Its *terminal branches* supply the epididymis and the body of the testicle; it anastomoses with the artery to the vas deferens, and gives off *cremasteric* twigs which anastomose with offsets of the cremasteric branch of the deep epigastric artery. The spermatic arteries sometimes spring by a common stem; one or both may arise from the renal.

The **ovarian arteries**, of the female, are similar in origin and in the first part of their course to the spermatic arteries of the male. Each vessel crosses the common iliac artery of its own side, inclines inwards at the margin of the pelvis, and runs somewhat tortuously between the layers of the broad ligament of the uterus, beneath the Fallopian tube, to the

ovary. Besides its terminal branches to the ovary, each artery gives off twigs to the Fallopian tube and the round ligament of the uterus, and sends to the uterus a considerable branch which enters into anastomosis with the uterine artery. During pregnancy the ovarian arteries are much enlarged.

THE COMMON ILIAC ARTERIES.

The common iliac arteries (Fig. 336), arising at the extremity of the aorta opposite the middle of the fourth lumbar vertebra, descend with an outward inclination, forming with one another an angle, which is greater in the female than in the male. Each vessel is about two inches in length, and divides at the level of the disc between the fifth lumbar vertebra and the sacrum into the external and internal iliac arteries. The artery of the right side has the lower extremity of the vena cava in contact with it externally and posteriorly, crosses the termination of the left common iliac vein, and lies in front of its own companion vein; the artery of the left side lies in front and to the outer side of the left common iliac vein. The sympathetic nerve-cords descend behind the arteries. Each of the arteries is crossed in front by the sympathetic branches to the hypogastric plexus and by the ureter, and, in the female, usually by the ovarian artery. The artery of the left side is crossed, in addition, by the superior haemorrhoidal artery. Both vessels are covered by peritoneum and overlaid by the intestines, the lower part of the ileum lying in front of that of the right side, the sigmoid flexure in front of that of the left. The lateral branches of the arteries are very minute; they ramify in the subperitoneal tissue, the ureter, and the psoas muscle.

The Internal Iliac Artery.

The internal iliac artery (Figs. 341, 342), from an inch to an inch and a half in length, descends into the pelvis from the bifurcation of the common iliac artery opposite the lumbo-sacral articulation, and divides near the margin of the great sacro-sciatic foramen into an anterior and posterior division. It lies in front of the lateral mass of the sacrum. It crosses in front of the external iliac vein, and its own companion vein lies behind and somewhat internal to it; the lumbo-sacral nerve-cord and the obturator nerve are also behind it. The ureter descends by its inner side; in front it is covered by the peritoneum.

The anterior division breaks up in an irregular manner into a number of visceral and parietal branches. The visceral branches are the superior and inferior vesical, the middle haemorrhoidal, and in the female the uterine and the vaginal. The parietal branches are the obturator, sciatic, and pudic. The branches of the posterior division of the artery are the gluteal, ilio-lumbar, and lateral sacral.

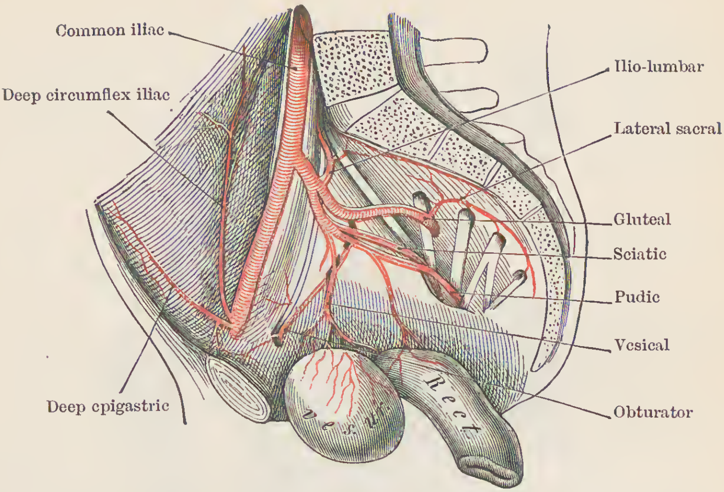


FIG. 341.—THE BRANCHES OF THE ILIAC ARTERIES. The usual arrangement. (C. Gegenbaur.)

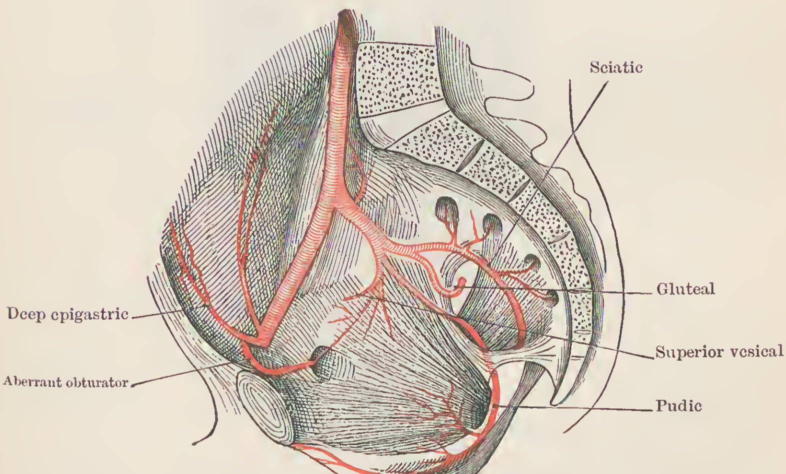


FIG. 342.—THE BRANCHES OF THE ILIAC ARTERIES. A less frequent arrangement than that represented in Fig. 341. (C. Gegenbaur.)

To face p. 452.

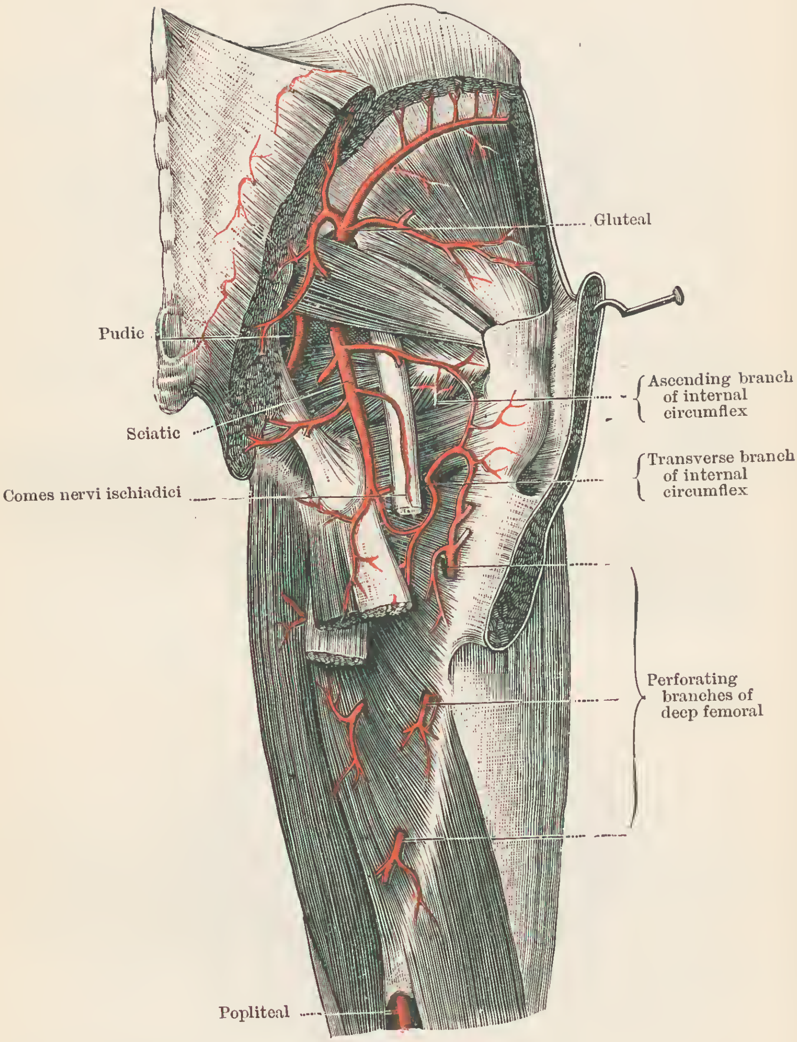


FIG. 343.—ARTERIES OF THE HIP AND THE POSTERIOR REGION OF THE THIGH. (L. Testut.)

To face p. 453.

The **superior vesical artery** (Fig. 342) is in the foetus the main continuation of the internal iliac artery. It passes forwards and upwards to the side of the bladder, and is thence continued upwards as an impervious cord, the *obliterated hypogastric artery*, to the umbilicus. The hypogastric arteries are in foetal life important vessels, carrying the blood to the placenta. Besides its branches to the bladder, the superior vesical artery usually furnishes the slender *artery of the vas deferens* which accompanies the spermatic duct to the testicle and anastomoses with the spermatic artery.

The **inferior vesical artery** descends to the lower part of the bladder, and in the male to the prostate gland. Its terminal branches anastomose with offsets of the superior vesical artery.

The **vaginal artery**, of the female, takes the place of the prostatic portion of the inferior vesical artery of the male. It supplies the lower part of the vagina, and anastomoses with its fellow of the opposite side and with the pudic and uterine arteries.

The **middle haemorrhoidal artery** passes to the lower part of the rectum, and anastomoses with the superior and inferior haemorrhoidal arteries.

The **uterine artery**, in the female, runs inwards and upwards in a tortuous manner between the layers of the broad ligament. It distributes many branches to the uterus, and anastomoses with the ovarian and vaginal arteries.

The **obturator artery** (Fig. 341) runs forwards and downwards on the pelvic wall, passes through the obturator notch in the thyroid foramen, and, under cover of the obturator externus muscle, divides into internal and external terminal branches. It is placed a little below the ilio-pectineal line, beneath the obturator nerve, and above the companion vein. Within the pelvis it detaches *iliac* and *pubic branches* which anastomose with offsets of the ilio-lumbar and deep epigastric arteries. The *internal terminal branch* passes downwards, supplies the upper ends of the adductor muscles, and anastomoses with the internal circumflex artery. The *external terminal branch* passes outwards below the acetabulum and, after furnishing a branch which enters the hip-joint through the cotyloid notch, supplies the muscles upon the back of the capsule and anastomoses with the sciatic and internal circumflex arteries. The obturator artery is very frequently absent from the internal iliac, its place being taken by an aberrant obturator artery (Fig. 342) from the deep epigastric; the aberrant artery is formed by the enlargement of the anastomosing branches on the back of the pubis (p. 457).

The **sciatic artery** (Figs. 341, 343), one of the terminal branches of the anterior division of the internal iliac, descends upon the nerves of the sacral plexus and the pyriformis muscle, and, at the lower border of the muscle, escapes through the great sacro-sciatic notch to divide immediately into a number of branches. Most of these are *muscular* in their distribution and supply the lower part of the gluteus maximus and the adjacent muscles;

some reach the skin. The *coccygeal branch* perforates the great sacro-sciatic ligament and ramifies upon the back of the coccyx. The *comes nervi ischiadici*, a slender vessel, accompanies, for a variable distance, the great sciatic nerve. The terminal offsets of the sciatic artery anastomose with branches of the pudic, gluteal, obturator, internal circumflex, and first perforating arteries.

The **pudic artery** (*internal pudic artery*) (Figs. 341, 344), the smaller of the terminal branches of the anterior division of the internal iliac artery, descends by the anterior and inner side of the sciatic artery and escapes with it through the lower part of the great sacro-sciatic notch. Continuing its course it turns over the spine of the ischium to re-enter the pelvis by the lesser sacro-sciatic notch, having, as it lies upon the bone, a vein placed on each side of it, the pudic nerve internally, and the nerve to the obturator internus externally. From the lower margin of the ischial spine it runs forwards along the outer wall of the ischio-rectal fossa as far as the anterior extremity of the tuberosity, occupying in this part of its course a special canal formed by the obturator fascia, and having the dorsal nerve of the penis above it, and the perineal branches of the pudic nerve below it. In the anterior part of the perineum it pierces the base of the triangular ligament and ascends between its layers, lying close to the bone, in the substance of the compressor urethrae muscle. Immediately below the symphysis it perforates the anterior layer of the ligament and descends along the dorsum of the penis under the name of the dorsal artery of the penis.

Branches of the pudic artery. Small *muscular* offsets are given to the obturator internus and the neighbouring muscles; they anastomose with branches of the sciatic artery. The *inferior haemorrhoidal* artery or arteries arise in the posterior part of the perineal space and pass forwards and inwards to the anus supplying the integument, the external sphincter, and the levator ani, and anastomosing with the middle haemorrhoidal artery. The *superficial perineal arteries*, one or two in number, arising about the middle of the perineum, pass forwards, generally superficially to the superficial transverse muscle and, perforating Colles's fascia, are continued to the scrotum where they supply the integument and the subcutaneous tissue and anastomose with the superficial pudic branches from the femoral artery. The *transverse perineal artery*, a small vessel, is given off in close connection with the superficial perineal; it passes inwards to the central point of the perineum, supplying the muscular and subcutaneous tissue. The *artery of the bulb* arises immediately after the parent trunk has entered the space between the layers of the triangular ligament. It runs forwards and inwards and, by the side of the urethra, pierces the anterior layer of the ligament to supply the bulb. The *artery of the corpus cavernosum*, given off a little above the artery of the bulb, perforates the anterior layer of the ligament and immediately enters the crus; it runs forwards to the anterior extremity of the cavernous body. The *dorsal artery of the penis* pierces the

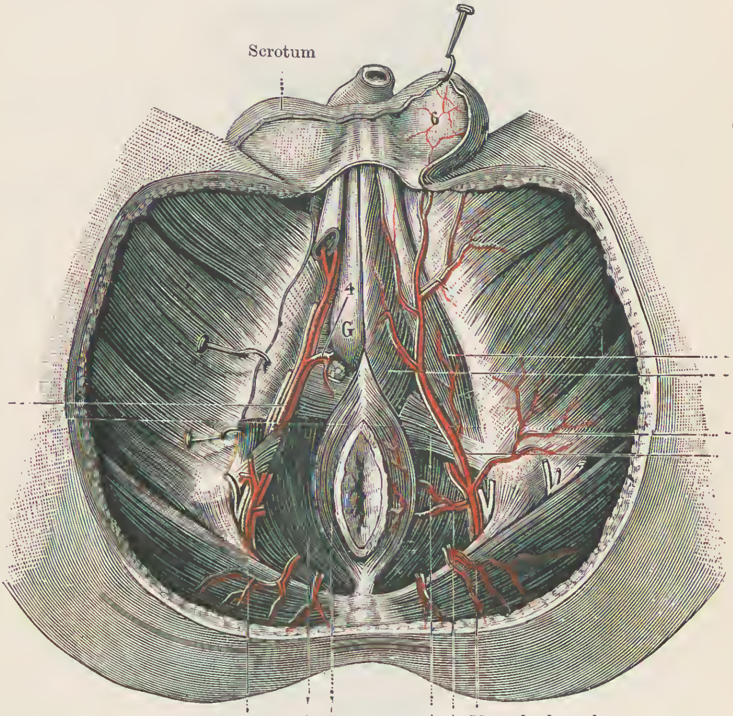


FIG. 344.—THE ARTERIES OF THE PERINEUM. On the left side a superficial dissection, on the right a deep dissection. (L. Testut.)

To face p. 454.

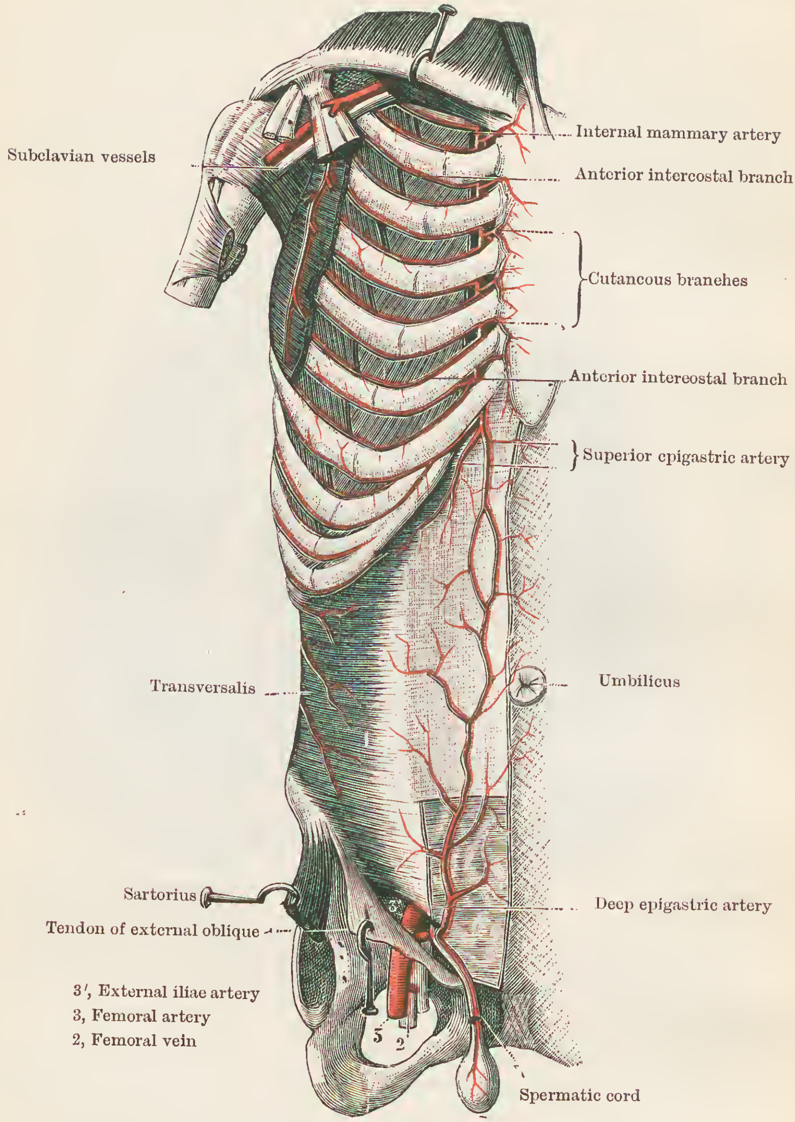


Fig. 345.—Arteries of the Thoracic and Abdominal Wall. (L. Testut.)

To face p. 455.

anterior layer of the triangular ligament close to the symphysis, courses through the suspensory ligament, and runs along the penis by the side of the single dorsal vein. Behind the glans the vessels of the opposite sides form an anastomotic circle. Many of the branches enter the corpus cavernosum and anastomose with its special artery.

The pudic artery of the female is similar to but smaller than the corresponding artery of the male; the superficial perineal branches ramify in the labia; the artery to the bulb enters the bulb of the vestibule, and the artery to the corpus cavernosum and the dorsal artery supply the clitoris.

Varieties of the pudic artery. All or any of the branches usually given off by the pudic after it has passed between the layers of the triangular ligament may be transferred to an *accessory pudic artery*, a vessel which arises within the pelvis from the stem of the pudic itself, or from one of the other branches of the internal iliac artery, and descends by the side of the prostate to perforate the triangular ligament, in front of the urethra. The *artery of the bulb* is very variable in size; it sometimes arises further back than usual and occupies a position which renders it liable to be wounded in the lateral operation for lithotomy.

The gluteal artery (Fig. 343), the largest branch of the internal iliac, passes backwards between the lumbo-sacral cord and the first sacral nerve; it emerges through the great sacro-sciatic foramen at the upper border of the pyriformis muscle, in company with the superior gluteal nerve, and immediately afterwards divides into a deep and a superficial branch. The *superficial branch*, the smaller of the two, ramifies on the deep surface of the gluteus maximus and anastomoses with offsets of the sciatic and lateral sacral arteries; one of its twigs, which is sometimes much enlarged, arches downwards across the back of the pyriformis muscle. The *deep branch*, subdividing into upper and lower branches, ramifies with the superior gluteal nerve between the gluteus medius and minimus muscles. The upper branch runs along the upper border of the gluteus minimus and anastomoses with the deep circumflex iliac and the external circumflex arteries; the lower branch crosses about the middle of the muscle and anastomoses with the external circumflex and sciatic arteries.

The **ilio-lumbar artery** (Fig. 341), similar in distribution to a lumbar artery, passes upwards and outwards, crossing behind the common iliac artery, the obturator nerve, and the psoas muscle. Under cover of the psoas it divides into a lumbar and an iliac branch. The *lumbar branch* ascends beneath the psoas to the quadratus lumborum muscle, supplies a spinal twig, and anastomoses with the lower lumbar arteries. The *iliac branch* passes outwards beneath the psoas, pierces the iliacus, and, on the surface of the bone, divides into numerous branches which supply the muscles, furnish nutrient vessels to the ilium, and anastomose with offsets of the obturator, external circumflex, and circumflex iliac arteries.

The **lateral sacral arteries** (Fig. 341) are usually two in number, a superior

and an inferior. The *superior* descends to the first sacral foramen, through which it passes backwards to supply the muscles and integument posteriorly. The *inferior* descends by the inner edges of the lower anterior foramina as far as the coccyx. It furnishes branches which pass backwards through the foramina, supplying the walls of the spinal canal and emerging behind, where they distribute twigs to the muscles and to the integument, and anastomose with branches of the gluteal and sciatic arteries. The lateral sacral arteries also furnish some small branches to the rectum and others which anastomose on the front of the sacrum with offsets of the middle sacral artery.

The External Iliac Artery.

The external iliac artery (Fig. 341) continues the line of the common iliac, and stretches from the level of the lumbo-sacral articulation to the lower border of Poupart's ligament, where it is continued into the femoral artery. It is from three and a half to four inches in length, and lies behind the lower two-thirds of a line drawn upon the surface from a point about half an inch below and to the left of the umbilicus to Poupart's ligament midway between the anterior superior spine and the pubic symphysis. It rests behind upon the iliac fascia and is placed above the margin of the true pelvis, at first to the inner side of and afterwards in front of the psoas muscle. Its companion vein lies at first behind and afterwards by its inner side. The ureter frequently crosses in front of it at its upper end; the spermatic vessels and the genital branch of the genito-crural nerve descend in front of it, crossing it obliquely from without inwards. At the lower end the deep circumflex vein passes inwards in front of it. It is surrounded by numerous lymphatic glands, is covered by the peritoneum, and is crossed on the right side by the lower part of the ileum, on the left by the sigmoid flexure. A very delicate sheath of subperitoneal areolar tissue envelops the artery and vein as they descend upon the iliac fascia. Its branches are the deep epigastric and the deep circumflex iliac; in addition a number of very minute twigs are supplied to the surrounding lymphatic glands.

The **deep epigastric artery** (Fig 345) takes origin about a fourth of an inch above Poupart's ligament, and, coursing in the fascia transversalis, passes at first inwards and then turns upwards, by the inner margin of the deep abdominal ring, towards the sheath of the rectus muscle, which it enters some little distance below the semilunar fold of Douglas. In its subsequent course it passes up behind the muscle and finally enters its substance, a little above the umbilicus, to anastomose with the superior epigastric of the internal mammary. Its branches are numerous but small. *Pubic* twigs descend behind the pubis and anastomose with branches of the obturator artery. The *cremasteric*, a slender branch, descends upon the cord or round ligament, anastomosing with branches of the spermatic or ovarian artery. Numerous

muscular branches ramify in the abdominal wall and anastomose with offsets of the circumflex iliac, ilio-lumbar, lumbar, and lower intercostal arteries. An *aberrant obturator artery* springs from the commencement of the deep epigastric trunk in about 30 per cent. of the cases. It is due to an enlargement of one of the pubic branches: it descends to the obturator notch usually by the outer side of the crural canal; in rare cases, however, it passes by the inner margin of the crural ring, a position in which it is in danger of being wounded in the operation for the relief of a strangulated femoral hernia.

The **deep circumflex iliac artery** (Fig. 341) springs from the outer side of the main stem in close proximity to the origin of the deep epigastric. It passes outwards and upwards behind Poupart's ligament to the anterior superior spine, and is then continued backwards along the iliac crest. It lies in the deep layer of fascia of the abdominal wall and furnishes numerous branches to the muscles of the upper part of the thigh and the lower part of the abdomen; it anastomoses with the deep epigastric, gluteal, ilio-lumbar, and lumbar arteries. One branch, frequently of some size, ascends immediately above Poupart's ligament, between the transversalis and internal oblique muscles.

Surgical anatomy of the abdominal arteries. Ligature of the *abdominal aorta* has been performed, but hitherto without success. The spot most suitable for the operation is about an inch above the bifurcation, and could be reached by an incision made along the linea alba, having the umbilicus as its centre. The descending branches from the aortic to the hypogastric plexus of sympathetic nerves which lie upon the sides of the vessel should be carefully avoided. The vena cava lies to the right side. The *common iliac artery* has been successfully tied. It may be easily reached through a median incision from the symphysis pubis to the umbilicus, and in this way also the *internal iliac* may be secured. Surgeons, however, in tying either of the two vessels, have usually adopted a method which, if properly carried out, saves the peritoneum from injury. A curved incision is carefully made through the abdominal wall down to, but not including, the peritoneum, and the serous membrane is stripped from the iliac fascia and pushed upwards until the artery is reached. The incision commences near the inner end of and a little above Poupart's ligament, passes upwards and outwards for a little distance parallel to the ligament, and then bends upwards and inwards. The incision must not, at its lower end, be carried so far inwards as to wound the superficial abdominal ring or the cord; if it come too near Poupart's ligament the deep circumflex iliac vessels would be endangered; if it be placed too far above Poupart's ligament the deep abdominal ring might be injured; the deep epigastric artery may be exposed at the inner part of the wound. The veins which accompany the iliac arteries are very large, and numerous sympathetic branches are in close proximity and should be carefully cleared aside. In the case of the internal iliac artery the ureter must be avoided. The *external iliac artery*

is secured through an incision very similar to, but not so extensive as that required for either of the other two vessels. It is made a little above Poupart's ligament and is slightly bent upwards at its outer end. On account of the presence of the large branches below, the ligature is applied about an inch and a quarter above Poupart's ligament.

The spot at which the *gluteal artery* escapes from the pelvis is opposite the lower end of the upper third of a line drawn from the posterior superior iliac spine to the top of the great trochanter, the thigh being rotated inwards. The *sciatic* and *pudic* arteries escape from the pelvis at a spot which is opposite the upper end of the lower third of a line drawn from the posterior superior spine of the ilium to the tuberosity of the ischium. These vessels may be ligatured at the spots indicated, but, as they lie very deeply, the operation in each case is difficult and demands a free incision. The left pudic artery, in the wall of the ischio-rectal fossa, may be injured by the knife, should the point be turned too much backwards, at the close of the first incision in the operation of lateral lithotomy. The *artery of the bulb*, when arising further back than usual, will probably be cut in the same incision, and may require ligature.

The Femoral Artery.

The femoral artery (Fig. 346), the continuation of the external iliac, enters the thigh, from under Poupart's ligament, midway between the anterior superior spine and the symphysis pubis. It descends through the upper two-thirds of the thigh as far as the margin of the opening in the insertion of the adductor magnus muscle, through which, as the popliteal artery, the trunk is continued to the back of the limb. It is at first placed in front of the head of the femur, then, owing to the inclination of the neck, lies at some little distance from the bone; still lower it descends by the inner side of the shaft. In the upper third of the thigh it lies in Scarpa's triangle; in the remainder of its course it occupies Hunter's canal. *In Scarpa's triangle* it rests successively upon the psoas, pectineus, adductor brevis, and adductor longus muscles and is comparatively superficial, being covered only by the fascia. At first the vein is internal to it, but lower down gradually passes behind it; the deep femoral vein is likewise at the lower part placed behind it; occasionally a large tributary of the internal saphenous vein ascends in the superficial fascia in front of the lower part of this portion of the artery. The anterior crural nerve lies external to it in its upper part, and, a little below Poupart's ligament, breaks up into its terminal branches, of which the internal cutaneous nerve descends in front of the artery, gradually crossing it, while the internal saphenous and the nerve to the vastus internus pass downwards by its outer side. At the apex of Scarpa's triangle the artery passes under cover of the sartorius muscle and enters *Hunter's canal;* in this portion of its course it is covered in front and internally by the sartorius and, bound down by aponeurotic fibres, rests in

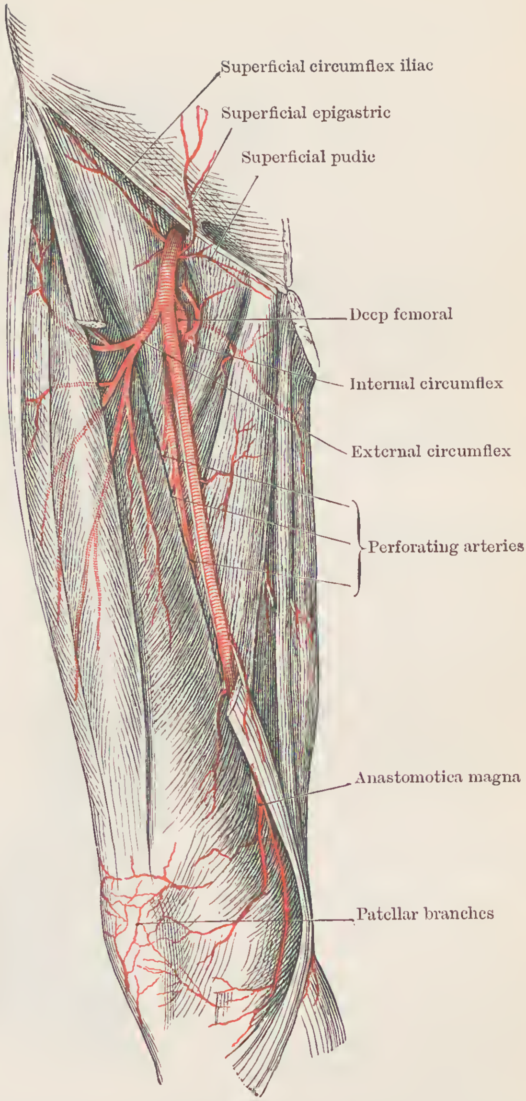


FIG. 346.—THE FEMORAL ARTERY AND ITS BRANCHES. The femoral artery is represented as drawn outwards a little in its upper part to show the origin of the deep femoral from its posterior surface. (C. Gegenbaur.)

To face p. 458.

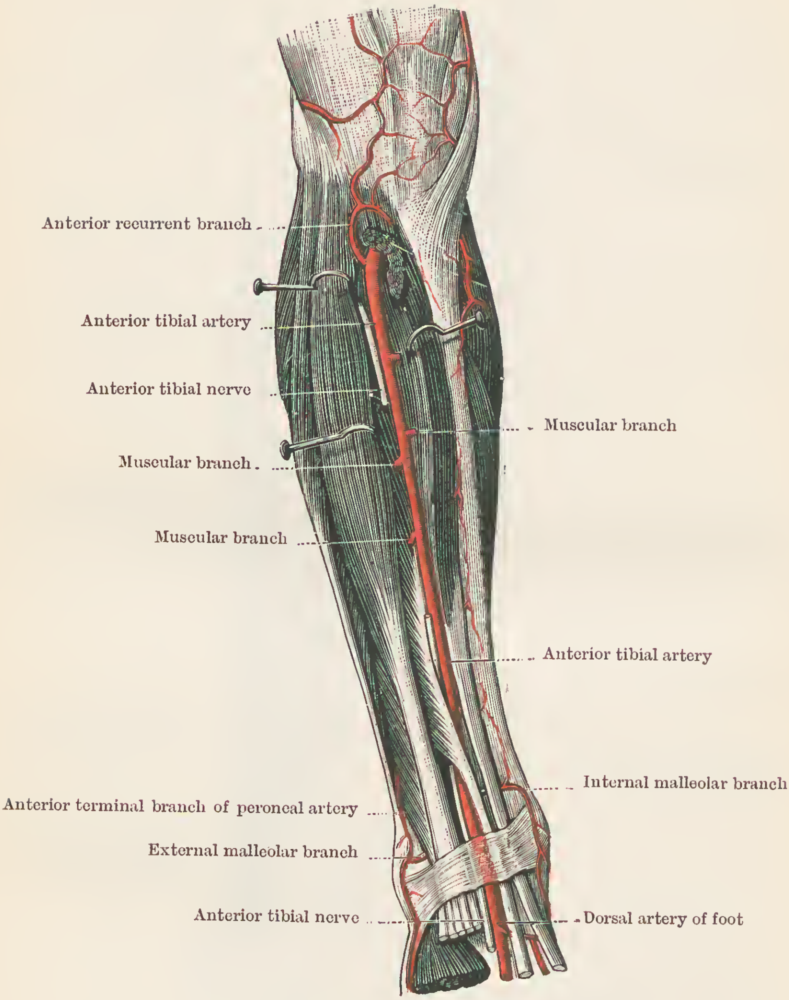


FIG. 347.—THE ANTERIOR TIBIAL ARTERY. (L. Testut.)

To face p. 459.

the angle between the insertions of the adductors longus and magnus behind, and the vastus internus muscle externally. Within the canal the vein lies behind it, gradually passing to the outer side below, and the long or internal saphenous nerve is placed in front of it; the nerve to the vastus internus descends in front of the canal, a little external to and in front of the line of the artery.

In the neighbourhood of the saphenous opening the femoral artery gives off a number of small superficial branches which supply the lymphatic glands of the groin and the skin and superficial fascia in the vicinity; they are—the *superficial circumflex iliac*, passing upwards and outwards; the *superficial epigastric*, passing upwards; and the *upper* and *lower superficial pudic* arteries, directed towards the pubic region and the scrotum;—each of these vessels anastomoses with the superficial branches of the correspondingly named deep trunk. A number of irregular muscular branches are given off at intervals. The most important branch is the deep femoral artery. Near the lower end of the stem the anastomotica magna is detached.

The **deep femoral artery** (Fig. 346) springs from the femoral about an inch and a half below Poupart's ligament; it is of considerable size and the portion of the femoral artery above its origin is, on that account, frequently named the "common femoral," and the portion below the "superficial femoral." It descends at first by the outer side of, and afterwards behind the parent trunk, from which it is separated by the femoral and deep femoral veins and the adductor longus muscle, and it rests successively upon the iliacus, pectineus, adductor brevis, and adductor magnus muscles, through the last mentioned of which it finally passes in the lower part of the middle third of the thigh, much reduced in size, as the last perforating artery. It gives off the external and internal circumflex and the perforating branches.

The *external circumflex artery* usually springs from the deep femoral artery near its commencement, but very frequently from the femoral itself. It passes outwards under cover of the rectus and sartorius muscles and breaks up into three sets of branches—(1) the *ascending*, which pass upwards under cover of the tensor vaginae femoris muscle to anastomose with branches of the gluteal artery; (2) the *transverse*, which sink into the substance of the crureus and vastus externus muscles and anastomose with the upper perforating arteries; and (3) the *descending*, which pass downwards upon the quadriceps muscle, supplying it, and anastomose with the lower perforating arteries and the external articular branches of the popliteal.

The *internal circumflex artery* usually springs from the commencement of the deep femoral, but, like its neighbour, it is frequently transferred to the main trunk. It passes backwards between the psoas and pectineus muscles, supplying the adductor muscles, anastomosing with the obturator artery, and giving off an *articular branch* which enters the joint through the cotyloid notch. It then divides into two branches (Fig 343), one of which, the *ascending*, passes upwards behind the hip-joint to anastomose at the upper

border of the quadratus femoris with the sciatic artery, while the other, the *transverse*, passes backwards between the lower border of the quadratus femoris and the upper border of the adductor magnus muscles to assist in the supply of the muscles of the back of the limb and anastomose with the sciatic and upper perforating arteries.

The *perforating arteries* (Fig. 343), four in number, including the terminal part of the deep femoral, pass backwards through the adductor magnus, close to its insertion, to supply the back of the limb; they anastomose with the sciatic, with the internal and external circumflex arteries, with one another, and with the muscular and articular branches of the popliteal artery. They are very variable in size and number, being frequently reduced to two or three. The *first*, commonly the largest, pierces the adductor brevis before passing through the adductor magnus, and breaks up into its terminal branches under cover of the gluteus maximus; the *second* usually pierces the adductor brevis but may pass backwards by its lower border.

The **anastomotica magna artery** (Fig. 346) springs from the femoral near the lower end of Hunter's canal, and almost immediately divides into two branches, superficial and deep. The *superficial branch* descends on the deep surface of the sartorius, with the internal saphenous nerve, to the upper and inner part of the leg, where it supplies the superficial parts, and anastomoses with the internal articular arteries; the *deep branch* descends in front of the tendon of the adductor magnus on the surface of the vastus internus muscle, or within its substance, and anastomoses with the upper internal articular branches of the popliteal artery.

Varieties of the femoral artery. Sometimes, but very rarely, the femoral artery is absent or much reduced in size, its place being taken by an enlarged comes nervi ischiadici of the sciatic; this is the course of the main artery of the limb in birds.

Surgical anatomy of the femoral artery. The course of the artery may be marked on the surface by the upper two-thirds of a line drawn from a point on Poupart's ligament, midway between the anterior superior spine and the symphysis, to the adductor tubercle of the inner condyle of the femur. The ligature is usually applied at the apex of Scarpa's triangle. There is frequently found in the superficial fascia a large tributary of the internal saphenous vein ascending along the line of operation. The sartorius muscle is exposed, and its inner border forms the guide to the vessel. The internal cutaneous nerve descends here in front of the vessel, the femoral vein is behind, and the long saphenous nerve and nerve to the vastus internus are external; the vein and the internal saphenous nerve lie very close to the artery. The femoral artery may be secured in Hunter's canal. An incision is made along the line of the artery in the middle third of the limb; the long saphenous vein lies in the subcutaneous tissue to the inner side of the incision; the fascia is cut through along the outer edge of the sartorius and the muscle is drawn inwards. If the limb be abducted the tendon of the adductor magnus will be made tense,

and will serve as a guide to the position of the vessel. When the canal has been opened the long saphenous nerve is found in front of the artery, and the femoral vein lies behind; the nerve to the vastus internus may be seen before the canal is opened. The upper part of the femoral, above the origin of the deep femoral, is unfavourable for ligature on account of the proximity of the large branches; the circulation through it may be controlled by pressure directed backwards.

The Popliteal Artery.

The popliteal artery, the continuation of the femoral trunk, extends through the lower third of the thigh and the upper sixth of the leg, from the opening in the insertion of the adductor magnus to the lower border of the popliteus muscle, where it divides into the anterior and posterior tibial arteries. It is directed at first downwards and inwards to gain, opposite the back of the knee-joint, the middle line of the popliteal space, and then descends vertically, resting first on the capsule of the joint and afterwards on the popliteus muscle. At the upper end it is covered by the semimembranosus, below it passes under cover of the gastrocnemius, and is crossed by the plantaris. The companion vein is at first external to the artery, but crosses it gradually, resting closely upon its posterior surface about the middle of the space, and gains its inner side below; the short saphenous vein ascends superficially behind the lower part of the artery to join the popliteal vein. The internal popliteal nerve lies behind the artery and vein in the middle of the space, but below is placed by their inner side. The branches of the artery are divided into two groups, muscular and articular.

The **muscular branches** are arranged in two sets, upper and lower in position. The *upper set* is formed of three or four vessels, which supply the lower ends of the hamstring muscles and anastomose with the lower perforating and upper articular arteries. The *lower set* includes two branches, the *outer* and *inner sural arteries*, which supply the gastrocnemius, the plantaris, and the upper part of the soleus, and detach slender twigs to descend subcutaneously upon the calf.

The **articular branches** are five in number, the two upper encircling the bone above the joint, the two lower coursing round the bones below the joint, and the middle or azygos artery piercing the posterior ligament to enter the joint. The *upper articular arteries, external* and *internal*, the external being the larger, are directed, above the heads of the gastrocnemius, and under cover of the hamstring muscles, to the front of the lower end of the femur, where they anastomose with one another, and with the upper muscular branches, the external circumflex, and the anastomotica magna from above, and with the lower articular arteries from below. The *lower articular arteries, internal* and *external*, the internal being the larger, are directed transversely upon the surface of the popliteus muscle, and pass

respectively under cover of the internal and external lateral ligaments to ramify over the front of the joint, anastomosing with one another, with the upper articular arteries from above, and with the recurrent branches of the anterior tibial artery from below. The articular arteries supply small branches to the capsular ligament and to the surrounding muscles. The *azygos articular artery*, arising opposite the middle of the joint, pierces the posterior part of the capsular ligament to supply the crucial ligaments and the ligamentum mucosum.

Varieties of the popliteal artery are not frequent; it sometimes divides into its terminal branches a little higher than usual. The vein is frequently found double in the lower part of the popliteal space and occasionally even in the upper part of the space.

Surgical anatomy of the popliteal artery. The popliteal artery is seldom ligatured, as in most cases the surgeon would prefer to deal with the femoral. The artery is so deeply placed in the fat of the space and is so very closely associated with the vein, especially in the middle of the space, that the operation would be specially difficult and dangerous. The vessel has been secured near its lower end between the heads of the gastrocnemius by a median incision. In this operation the short saphenous vein and the sural arteries are to be avoided. The internal popliteal nerve is first met with; the vein lies on the deep surface of the nerve, and both are internal to the artery and somewhat superficial to it. The artery has also been ligatured in the lower part of the thigh, as it lies between the adductor magnus and semimembranosus muscles. The incision is made behind the tendon of the adductor magnus, the sartorius is drawn backwards, and the semimembranosus exposed; the artery here lies close to the bone with the vein on its deep surface.

The Anterior Tibial Artery.

The anterior tibial artery (Fig. 347) springs from the termination of the popliteal stem at the lower border of the popliteus muscle, and almost immediately passes forwards, between the heads of the tibialis posticus muscle, through the interosseous membrane. It then passes downwards as far as the level of the ankle-joint, beyond which it is continued as the dorsal artery of the foot. As it descends it rests in the upper two-thirds of its course upon the interosseous membrane, in the lower third, upon the tibia. In the upper part it is deeply placed, being covered by the muscles between which it lies; internally the tibialis anticus, externally the extensor digitorum longus in the upper third of the leg, and the extensor hallucis longus below; but near the ankle, as the muscular fibres give place to tendon, the artery becomes comparatively superficial. About, or a little above the level of the ankle it is obliquely crossed from without inwards by the tendon of the extensor of the great toe. Two venae comites accompany it, one lying in front, the other behind. The anterior tibial nerve, which

gradually approaches it from the outer side in the upper fourth of the leg, descends for a little distance in front of it, but at the ankle again falls back to its outer side. The branches are small and numerous, and are divided into three sets—recurrent, muscular, and malleolar.

The **posterior recurrent branch**, often absent, is given off before the artery pierces the interosseous membrane, and ascends on the deep surface of the popliteus muscle to anastomose with the lower articular branches of the popliteal. The **anterior recurrent branch** takes origin immediately after the artery has pierced the membrane, and passes upwards through the tibialis anticus to end, like the posterior branch, in anastomosis with the lower articular arteries. The **muscular branches**, very numerous, supply the muscles of the front of the leg. Before the artery pierces the membrane, a slender branch is distributed to the upper part of the soleus. The **malleolar branches** pass from the main stem transversely behind the tendons immediately above the ankle-joint; the *internal*, the smaller, ramifies upon the inner malleolus and anastomoses with the internal malleolar branch of the posterior tibial artery and with the internal branches of the dorsal artery of the foot; the *external*, usually a little lower in position than the internal, is distributed around the outer malleolus and anastomoses with the anterior and posterior terminal divisions of the peroneal artery.

The Dorsal Artery of the Foot.

The dorsal artery of the foot (Fig. 348), the continuation of the anterior tibial artery, passes forwards from a spot opposite the middle of the ankle-joint to the posterior extremity of the interspace between the metatarsal bones of the first and second toes, where it sinks into the sole to inosculate with the termination of the external plantar artery. It lies upon the surface of the tarsal bones, being bound down by a strong layer of connective tissue; the tendon of the long extensor of the great toe lies to its inner side, and before it dips into the sole it is crossed by the first tendon of the extensor digitorum brevis. It is accompanied by two venae comites and by the inner terminal branch of the anterior tibial nerve, which is usually placed along its outer side. As it passes forwards on the dorsum of the foot it gives off one or two small branches from its inner side, and from the outer side the tarsal and metatarsal branches. Before it sinks into the sole it detaches the first dorsal interosseous artery; in the sole it gives off the arteria princeps hallucis.

The **internal branches**, small and irregular, ramify over the inner side of the tarsus and anastomose with branches of the internal plantar and the internal malleolar arteries. The **tarsal artery** passes outwards under cover of the extensor brevis muscle in company with the outer terminal branch of the anterior tibial nerve, and breaks up into twigs which supply the surrounding parts and anastomose with branches of the external malleolar, the external plantar, and the metatarsal arteries.

The **metatarsal artery** passes outwards upon the bases of the metatarsal bones, underneath the extensor tendons. It detaches the dorsal interosseous arteries of the three outer spaces. The *dorsal interosseous branches* pass forwards upon the interosseous muscles and at the clefts of the toes divide, like the corresponding arteries of the hand, into dorsal collateral branches, which run forwards upon the digits, anastomosing on the sides of the toes with the branches of the plantar digital vessels. Each interosseous trunk is connected with the external plantar artery by a *posterior perforating branch*, and with the plantar digital artery of its space by an *anterior perforating branch*; the most external trunk gives off a branch for the outer side of the little toe. The dorsal arteries of the foot are comparatively larger than those of the hand. *Recurrent branches* pass from the metatarsal artery to anastomose with offsets of the tarsal artery. The **first dorsal interosseous artery**, given off before the main stem enters the sole, passes forward and supplies digital branches to both sides of the great toe and the inner side of the second toe. and is connected by an anterior perforating branch with the plantar digital artery of its space.

The **arteria princeps hallucis** (Fig. 350), the innermost plantar digital artery, springs from the termination of the dorsal artery of the foot; it passes forwards in the first interosseous space, detaches a branch to the inner side of the great toe, aud divides to supply the contiguous sides of the great and the second toes. Its innermost branch inosculates with the termination of the internal plantar artery.

The Posterior Tibial Artery.

The posterior tibial artery (Fig. 349), arising from the termination of the popliteal trunk, at the lower border of the popliteus muscle, descends upon the back of the leg with a slight inclination inwards, resting in succession upon the tibialis posticus, the flexor longus digitorum, the lower end of the tibia, and the capsule of the ankle-joint; it terminates midway between the internal malleolus and the centre of the prominence of the heel, by dividing into the internal and external plantar arteries. In the upper two-thirds of its course it is deeply placed in front of the gastrocnemius and soleus muscles and a deep layer of the fascia. Lower down, by the inner margin of the tendo Achillis, it is comparatively superficial, being covered only by the fascia. It terminates under cover of the internal annular ligament and the origin of the abductor hallucis muscle. As it descends behind the malleolus it lies between the tendons of the flexor digitorum longus internally and the flexor hallucis longus externally, and occupies a special fibrous sheath placed between those of the tendons, and slightly superficial to them. It is accompanied through its whole course by two venae comites and by the posterior tibial nerve, which crosses it posteriorly from the inner to the outer side, about an inch and a half below the popliteus muscle. It gives off numerous small muscular branches,

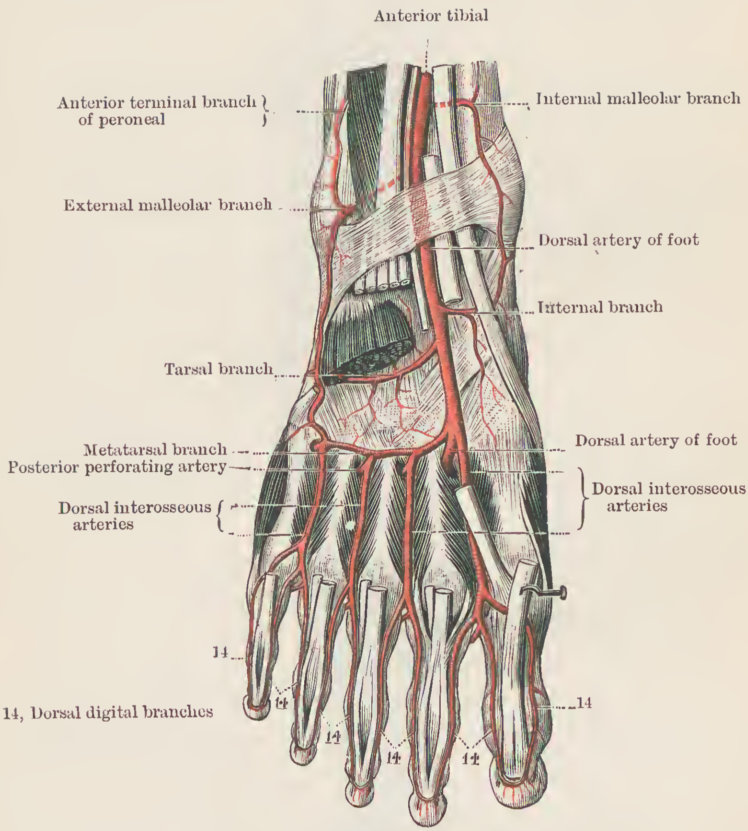


FIG. 348.—ARTERIES OF THE DORSUM OF THE FOOT. (L. Testut.)

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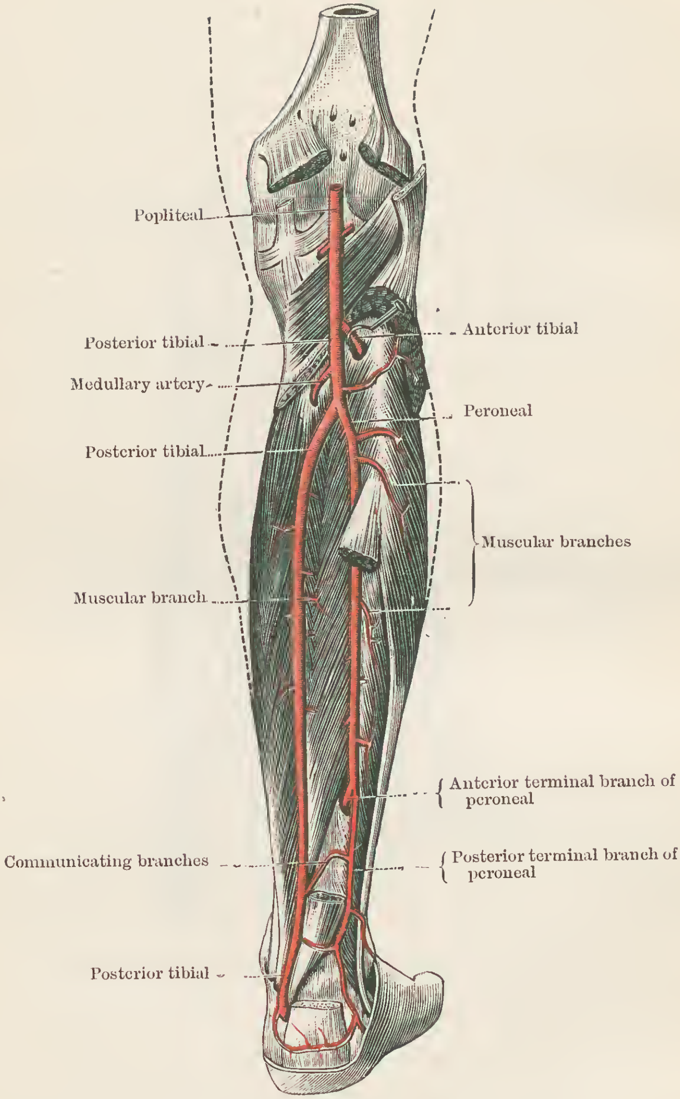

FIG. 349.—ARTERIES OF THE BACK OF THE LEG. (L. Testut.)

To face p. 465.

the medullary artery of the tibia, one or two communicating branches, the internal malleolar branches, and one branch of considerable size, the peroneal.

The **medullary branch**, the largest of its kind, arises near the upper end of the trunk, and enters the tibia. The **communicating branches**, one or two in number, pass outwards, in front of the tendons, about an inch or two inches above the heel, and communicate with similar branches from the peroneal artery. The **internal malleolar branches**, one or two in number, ramify upon the malleolus and anastomose with offsets of the anterior tibial and of the dorsal artery of the foot.

The **peroneal artery** (Fig. 349), springing about an inch and a half below the commencement of the parent trunk, passes downwards and outwards towards the fibula, and then descends by the inner border of that bone, under cover of, or sometimes in the substance of the flexor hallucis longus muscle. About an inch and a half above the ankle it terminates by dividing into anterior and posterior branches. It is accompanied by two venae comites. In its course it gives off a number of *muscular branches*, the *medullary artery* of the fibula, and, near the ankle, one or more *communicating branches* which join the corresponding branches of the posterior tibial. The *anterior terminal branch*, or *anterior peroneal* artery, passes forwards through the interosseous membrane, and descends in front of the lower tibio-fibular articulation; it forms connections with the external malleolar branch of the anterior tibial, and ramifies in front of the malleolus. The *posterior terminal branch* descends behind the lower tibio-fibular articulation, ramifies round the point of the external malleolus, and anastomoses with the arteries in front of the malleolus and with branches of the tarsal and external plantar arteries.

The External Plantar Artery.

The external plantar artery (Fig. 350), the larger terminal division of the posterior tibial, takes origin midway between the point of the internal malleolus and the prominence of the heel, under cover of the internal annular ligament and the origin of the abductor hallucis. It passes at first obliquely forwards and outwards towards the tuberosity of the fifth metatarsal bone; then, changing its direction, it bends inwards and forwards arching across the sole. It terminates at the proximal end of the first intermetatarsal space by inosculating with the extremity of the dorsal artery of the foot. As it passes forwards and outwards it is placed at first between the abductor hallucis and the calcaneum, and afterwards between the flexor digitorum brevis and the flexor accessorius. As it turns inwards, it lies in the space between the flexor digitorum brevis and the abductor minimi digiti and is thus comparatively superficial. In the last portion of its course it crosses the proximal extremities of the fourth, third, and second metatarsal bones, and is covered superficially

by the flexor tendons and the lumbricales, and, at its termination, by the adductor hallucis. It is accompanied by two venae comites, and has in the first part of its course the external plantar nerve on its inner side. Its branches are numerous, the most important being the plantar digital arteries.

Some *calcaneal branches* ramify upon the under surface of the os calcis, anastomosing with offsets of the posterior branch of the peroneal artery. *Muscular branches* supply the surrounding muscles, and detach *cutaneous twigs* which appear along the line between the middle and outer portions of the plantar fascia. These branches form anastomotic connections at the outer border of the foot with offsets of the tarsal and metatarsal branches of the dorsal artery. *Articular branches* run backwards from the arch. The *posterior perforating arteries*, three in number, ascend through the proximal extremities of the three outer intermetatarsal spaces and join the dorsal interosseous arteries.

The **plantar digital arteries** are four in number. The outermost passes forwards upon the flexor minimi digiti brevis and reaches the outer side of the fifth toe. The others, deeply placed, pass forwards upon the interosseous muscles of the three outer spaces, crossing above the transversus pedis muscle. Becoming superficial at the clefts of the toes, they communicate by means of the *anterior perforating arteries* with the dorsal interosseous arteries, and divide into collateral digital branches, the innermost of which supplies the outer side of the second toe. The *collateral digital branches* pass forwards upon the sides of the toes, anastomosing freely with one another and with the dorsal digital arteries.

The Internal Plantar Artery.

The internal plantar artery (Fig. 350), much smaller than the external, takes origin with it from the termination of the posterior tibial. It passes forwards between the abductor hallucis and the flexor digitorum brevis. At the base of the great toe it terminates by inosculating with the arteria princeps hallucis, the innermost plantar digital artery. It gives off a number of *muscular* and *cutaneous branches*, the more important of which anastomose at the inner border of the foot with branches of the dorsal artery. One or two *articular branches* pass deeply into the sole, and two or three slender *digital branches* accompany the digital branches derived from the internal plantar nerve, and inosculate at the three inner clefts with the plantar digital arteries.

Varieties of the arteries of the leg and foot. The *anterior tibial artery* is occasionally much reduced in size, and when this is the case it is usually reinforced or entirely replaced below by an enlarged anterior peroneal trunk. The *posterior tibial artery* is in like manner frequently much reduced or may be entirely deficient except in its lower part, and the

current of blood in these cases passes through an enlarged peroneal artery, and one or more of the communicating branches. The *dorsal artery of the foot* may be partly or wholly derived from the anterior peroneal artery. It may be reduced in size, some of its ultimate digital branches being transferred to the external plantar artery by an enlargement of the perforating vessels; on the other hand, it may be larger than usual, forming the greater part or even the whole of the plantar arch. The *external plantar artery* varies inversely with the dorsal artery of the foot. The *internal plantar artery* is very variable; it may extend no further than the muscles at the base of the great toe or, much enlarged, may give the chief supply to that digit.

Surgical anatomy of the arteries of the leg. The course of the *anterior tibial artery* may be marked on the surface by a line drawn from a point midway between the outer tuberosity of the tibia and the head of the fibula to a spot opposite the centre of the front of the ankle-joint. The vessel may be reached in any part of its course through an incision made along this line. It is most superficial in the lower third of the leg, and in this situation it is being gradually crossed from without inwards by the tendon of the extensor hallucis longus; its venae comites are in close apposition, and the anterior tibial nerve lies by its outer and anterior border. The *dorsal artery of the foot* continues the line of the anterior tibial from the middle of the ankle-joint to the posterior extremity of the first intermetatarsal space. It lies very close to the bone, and is enveloped in a firm layer of connective tissue. Two venae comites accompany it, and the nerve lies usually to the outer side. The *posterior tibial artery* is deeply placed in the upper two-thirds of the leg, but is comparatively superficial below. The lower part of a line drawn from the centre of the popliteal space to a spot midway between the point of the internal malleolus and the most prominent part of the heel would indicate the course of the vessel. It may be ligatured in the lower third of the leg through an incision made midway between the margin of the tendo Achillis and the inner border of the tibia; or it may be tied at the inner side of the ankle through a curved incision half an inch below the point of the malleolus. The venae comites are in close apposition to it, and the nerve is placed externally. It may be reached in the middle third of the leg through an incision about a quarter of an inch behind the inner border of the tibia; in this operation part of the origin of the soleus muscle must be divided.

THE VENOUS SYSTEM.

THE VEINS OF THE HEART.

The veins of the heart terminate in a common trunk, the coronary sinus.

The **coronary sinus** (Fig. 308), about an inch in length, lies in the posterior part of the auriculo-ventricular furrow, between the left auricle and ventricle, and opens into the right auricle, the orifice, which is guarded by the valve of Thebesius, being placed between the Eustachian valve and the auriculo-ventricular opening. The tributaries of the sinus are the left and right coronary veins, the posterior interventricular vein, and the oblique vein.

The **left or great coronary vein** (Fig. 308) runs in the auriculo-ventricular furrow, beginning in front and terminating behind in the left extremity of the sinus. Its chief tributary is the *anterior interventricular vein*, a vessel which, much larger than the anterior part of the coronary vein into which it falls, ascends in the anterior interventricular groove, receiving branches from the surface of both ventricles. The left coronary also receives from the surface of the left ventricle a number of *posterior cardiac veins*, one among which, sometimes larger than the others, is named the left marginal vein. Some of the posterior cardiac veins fall directly into the sinus.

The **right or small coronary vein** (Fig. 308) runs in the auriculo-ventricular furrow, beginning in front and terminating behind by falling into the right extremity of the sinus. It receives from the surface of the right ventricle a number of *anterior cardiac veins*, one among which is sometimes named the right marginal vein. The *posterior interventricular vein* ascends in the posterior interventricular furrow, and falls into the right extremity of the sinus, generally by a separate orifice, but in very close proximity to the opening of the right coronary vein. Both coronary veins receive, in addition to the tributaries from the ventricular walls, some small irregular vessels from the surface of the auricles.

The **oblique vein**, the remains of the left duct of Cuvier, descends in the vestigial fold of Marshall, and enters the left extremity of the coronary sinus. It is very slender and is frequently impervious. The orifices of all the veins which open into the sinus, with the exception of that of the oblique vein, are guarded by valves.

In addition to the large veins which open into the sinus, a number of very small veins, *venae minimae cordis*, run in the substance of the cardiac wall, and open into some of the pits of Thebesius in the right auricle.

The Vena Cava Superior.

The superior vena cava (Figs. 351, 359) is formed by the junction of the right and left innominate veins, and descends from behind the first

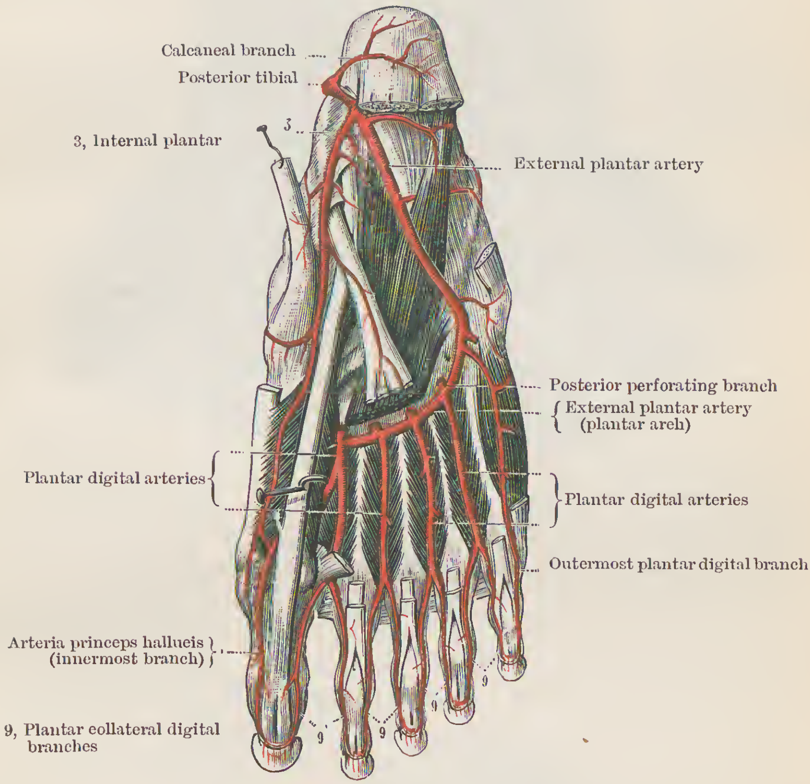

FIG. 350.—ARTERIES OF THE SOLE. (L. Testut.)

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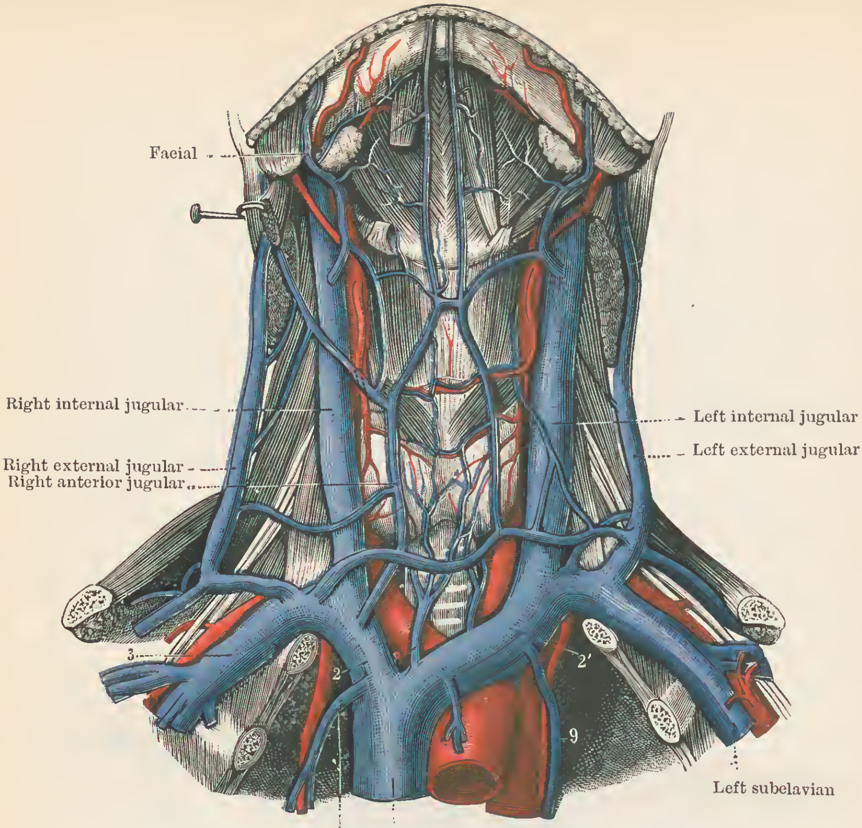

FIG. 351.—THE SUPERIOR VENA CAVA AND ITS BRANCHES. (L. Testut.)

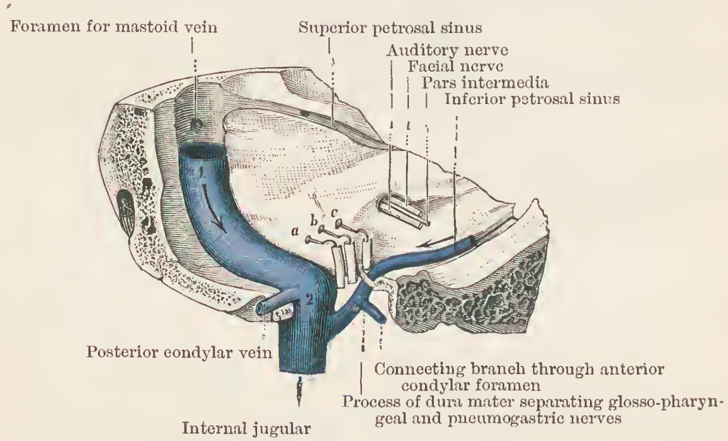

FIG. 352.—THE COMMENCEMENT OF THE INTERNAL JUGULAR VEIN, left side. *a*, Spinal accessory nerve; *b*, pneumogastric nerve; *c*, glosso-pharyngeal nerve; 1, lateral sinus; 2, dilated portion or bulb of the internal jugular. (L. Testut.)

To face p. 469.

right costal cartilage to the level of the third right costal cartilage, where it enters the right auricle. It is about three inches in length, and receives about half-way down the great azygos vein. Above the entrance of the azygos vein it is overlapped by the right pleura, and the right pneumogastric nerve lies behind it; below, it is enveloped except for a narrow line posteriorly, by the pericardium, and rests behind on the right bronchus and the right pulmonary artery and veins. On its left side it is in contact with the ascending portion of the aorta; the phrenic nerve descends on its right side. In addition to the larger tributaries, it receives some minute veins from the anterior mediastinum.

Right innominate vein (Fig. 351). This vessel is formed by the junction of the right internal jugular and subclavian veins. It is a little over an inch in length, and descends, with a slight inclination inwards, on the right side of the innominate artery, from behind the sternal end of the clavicle to the level of the first costal cartilage. It is in contact with the pleura externally and posteriorly; the phrenic nerve descends by its outer border, and the pneumogastric is placed behind it. In front of it lie some remains of the thymus gland and, on the deep surface of the clavicle, the origin of the sterno-hyoid muscle. Its lateral tributaries are the vertebral, the inferior thyroid, and the internal mammary veins; and it receives at its commencement the right lymphatic duct.

Left innominate vein (Fig. 351). The left innominate, formed by the junction of the left internal jugular and subclavian veins, is about three inches in length. Commencing behind the sternal end of the left clavicle, it passes to the right, descending slightly as it goes, and crosses behind the upper part of the manubrium and in front of the three great branches of the transverse portion of the aorta, to terminate behind the first right costal cartilage. It is placed above the arch of the aorta, and in front of it lie the remains of the thymus gland and the origins of the sterno-hyoid and sterno-thyroid muscles. Its lateral tributaries are the vertebral, inferior thyroid, internal mammary, left superior intercostal, and some small pericardial and thymic veins; and it receives at its commencement the thoracic duct. The innominate veins have no valves.

VEINS OF THE HEAD AND NECK.

The **vertebral vein** commences in the suboccipital triangle as a plexus of small vessels communicating with the occipital, deep cervical, and spinal veins. The plexus is continued downwards through the successive foramina, receiving as it descends some small *spinal* and *muscular branches*. Lower down the plexus gives place to a single vessel which emerges in front of the vertebral artery, crosses the subclavian artery, and terminates in the innominate vein. Close to its termination the vertebral vein is joined by the *deep cervical vein*, the *anterior vertebral vein* (a muscular branch from the front of the column), and as a rule

the *first intercostal vein.* One or two valves guard the termination of the vertebral vein.

The **deep cervical vein** commences in the *suboccipital plexus,* through which it is continuous with the *occipital veins.* Below the plexus, the vein, continued downwards, accompanies the deep cervical artery. It terminates in the vertebral vein.

The **inferior thyroid vein** (Fig. 351) descends in front of the trachea in company with its fellow of the opposite side, with which it is frequently united by transverse branches. The left vein terminates below in the left innominate vein, the orifice being guarded by a valve; the right vein either joins its fellow of the left side, or terminates separately in the angle of junction between the innominate veins or in the right innominate.

Internal Jugular Vein (Figs. 351, 352). This great vein, continuous with the lateral sinus, descends from the posterior part of the jugular foramen, and on its way lies by the outer side, first of the internal carotid and afterwards of the common carotid artery. It terminates behind the sternal end of the clavicle in the innominate vein. At its commencement in the jugular foramen it is somewhat dilated, and receives the inferior petrosal sinus. About an inch above its termination a couple of valves are found. Its lateral tributaries are the middle and superior thyroid, the lingual, facial, and pharyngeal veins; and in many cases it receives a communicating branch from the external jugular vein.

The **middle thyroid vein,** from the side of the thyroid body, crosses the common carotid artery a little below the level of the cricoid cartilage, and falls into the internal jugular. The **superior thyroid vein** (Fig. 353), accompanying the superior thyroid artery, passes outwards to the internal jugular, crossing the upper part of the common carotid artery.

The **lingual veins** (Fig. 353). Two small *venae comites* accompany the lingual artery, and eventually join with one another to form a stem which receives the much larger *ranine vein,* a vessel which, passing backwards from the tip of the tongue, crosses the outer surface of the hyo-glossus muscle immediately below the hypoglossal nerve, and receives on its way the sublingual and dorsal branches. The common lingual vein crosses the external and internal carotid arteries, and either falls directly into the internal jugular or unites with the terminal part of the facial vein. Occasionally the branches which make up the lingual vein enter the internal jugular separately.

The **facial vein** (Fig. 353) collects the blood from the anterior part of the scalp and from the face. It commences near the vertex of the head in a network which anteriorly is continued into the frontal vein. The *frontal vein* passes towards the root of the nose, communicating across the middle line with its fellow of the opposite side, and above the inner canthus unites with the *supraorbital vein,* a vessel which draws its supply from the lateral part of the forehead. The common trunk thus formed, the *angular vein,* is directed backwards and downwards, passing the inner canthus, and, below the orbit, is

continued into the facial vein. The angular vein receives numerous palpebral and nasal branches, and through its larger tributaries communicates freely with the veins of the orbit, and through them with the cavernous sinus. The facial vein passes backwards and downwards over the face, holding a straight course behind the facial artery, crossing on the deep surface of the zygomatici and the platysma. It receives from the front *nasal* and *labial branches*, and from behind *palpebral*, *glandular*, and *muscular twigs*, and a somewhat large *branch of communication* which comes forwards, upon the buccinator muscle, from the pterygoid plexus. In the neck the facial vein descends superficially over the digastric and stylo-hyoid muscles, crosses the external and internal carotid arteries, and falls into the internal jugular vein opposite the hyoid bone. In this part of its course it receives (*a*) from the front, *submental* and *glandular branches*, through which it communicates with the anterior jugular vein; (*b*) on its deep surface, the *inferior palatine vein* which accompanies the ascending palatine branch of the artery; and (*c*) from behind, the *anterior division of the temporo-maxillary vein*, through which it is brought into communication with the external jugular vein. A communicating branch frequently passes from the lower end of the facial, along the margin of the sterno-mastoid muscle, to the anterior jugular vein. At its lower end the facial occasionally receives the pharyngeal, lingual, and superior thyroid veins. It sometimes falls into the external jugular and occasionally into the anterior jugular vein.

The **pharyngeal veins** form, on the outer surface of the pharynx, a plexus which communicates above with the pterygoid plexus and, through the foramen lacerum medium, with the cavernous sinus. They open as one or two trunks into the facial or internal jugular.

SUBCLAVIAN VEIN (Fig. 351). This trunk is the continuation of the axillary vein. It commences at the outer border of the first rib, and terminates in the innominate vein behind the sternal end of the clavicle. It is placed in front of and a little lower than the subclavian artery, from which it is separated by the scalenus anticus muscle. The phrenic nerve, which crosses in front of the artery, passes behind the vein. Near the outer border of the sterno-mastoid it receives the external jugular vein. A couple of valves are found immediately external to the orifice of the tributary.

The **external jugular vein** (Fig. 351) is formed immediately behind the angle of the jaw by the union of the posterior auricular vein with the posterior division of the temporo-maxillary vein. It descends, lying in the superficial fascia, under cover of the platysma, and crosses the sterno-mastoid muscle, the posterior border of which it gains two or three inches above the clavicle. Close to the clavicle, a little behind the sterno-mastoid, it pierces the deep fascia and falls into the subclavian vein. Its lateral tributaries are the anterior jugular, the suprascapular, the transverse cervical, and the posterior jugular veins. It is very variable in size, and

is sometimes absent when the anterior jugular is large. It contains a valve a little above its lower extremity.

The *anterior jugular vein* (Fig. 351) takes origin in the inframaxillary region from a number of small vessels, which communicate laterally with the submental veins. It descends in the superficial fascia in front of the larynx and trachea, and near the clavicle perforates the deep fascia and is continued backwards, immediately above the bone, on the deep surface of the sterno-mastoid muscle, to terminate in the lower part of the external jugular vein. It is connected above the sternum with its fellow of the opposite side by a transverse branch, which crosses the lower part of the trachea. It is of very variable size. It frequently receives a communicating branch from the facial vein. In many cases it ends in the subclavian or innominate vein.

The *suprascapular* and *transverse cervical veins* accompany the corresponding arteries, and terminate in the external jugular, sometimes in a plexiform manner, a little above the clavicle, in front of the third portion of the subclavian artery.

The *posterior jugular vein* is of very variable size, and when well developed usually communicates above with the occipital vein. Descending behind the sterno-mastoid it falls into the external jugular vein some little distance above the clavicle.

The *posterior auricular vein* descends from the lateral part of the scalp where its radicles communicate with those of the temporal and occipital veins. It receives branches from the pinna and passes downwards, crossing the sterno-mastoid muscle, to the upper extremity of the external jugular vein.

The *temporo-maxillary vein*, a short trunk, lies in the lower part of the parotid gland. It is formed above, opposite the neck of the jaw, by the junction of the temporal and internal maxillary veins, and divides below, opposite the angle, into two divisions, the anterior of which descends to the facial, while the posterior, joining with the posterior auricular, forms the external jugular. Occasionally it passes entirely to the external jugular, which then usually, at its upper end, either gives to or receives from the lower end of the facial a communicating branch.

The *temporal vein* is formed immediately above the zygoma by the junction of a trunk formed by the union with one another of anterior and posterior superficial branches with a deep or middle temporal. The radicles of the *superficial branches* ramify over the lateral part of the scalp and communicate with the vessels in front and behind, and those of the other side; those of the *deep branch*, which pierces the temporal fascia, communicate with the deep temporal and orbital veins. The temporal vein crosses the zygoma behind and superficial to the artery, and unites opposite the neck of the jaw with the internal maxillary vein. It receives *anterior auricular*, *glandular*, *articular*, and *transverse facial branches.*

The *internal maxillary vein*, a short trunk, passes backwards, under cover of the ramus of the jaw, from the pterygoid plexus, and joins the temporal vein.

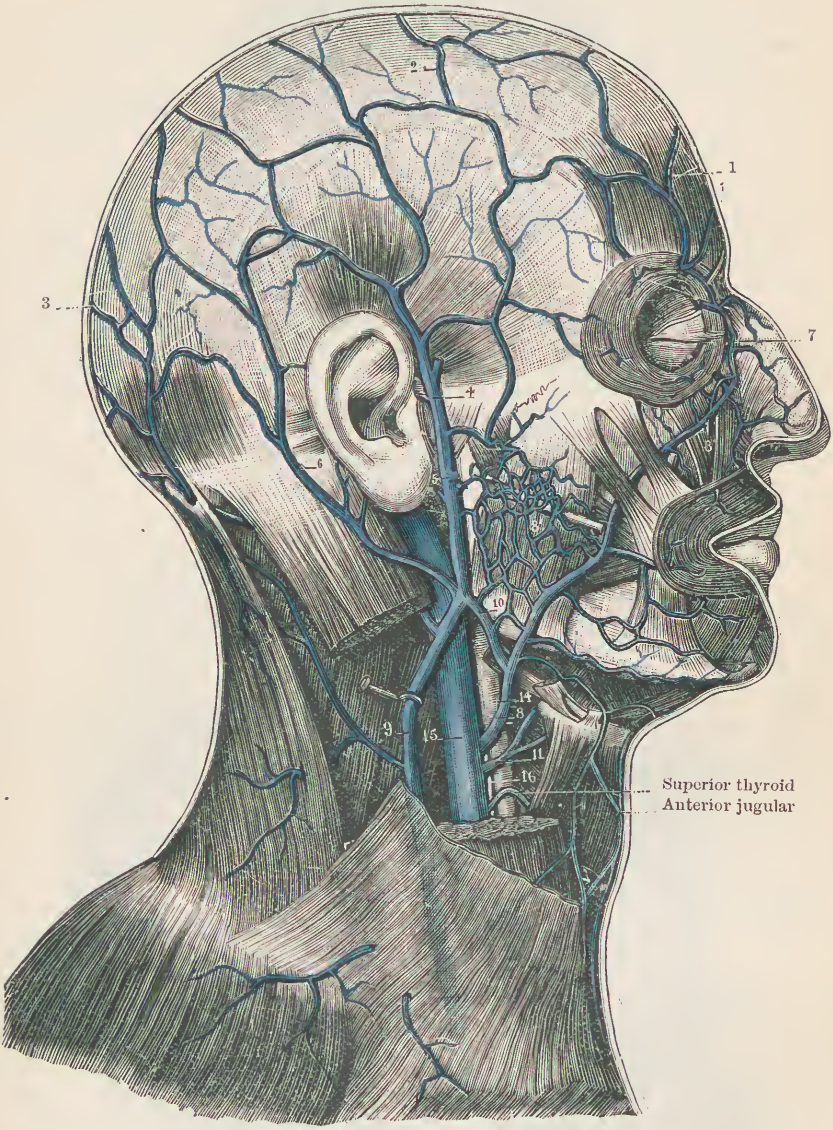

FIG. 353.—SUPERFICIAL VEINS OF THE HEAD AND NECK. 1, Frontal; 2, superficial parietal veins communicating with frontal, temporal, and occipital; 3, occipital; 4, superficial temporal; 6, posterior auricular; 7, angular; 8, facial; 8′, 10, connections between facial and temporal veins; 9, external jugular; 11, lingual; 14, external carotid artery; 15, internal jugular; 16, pneumogastric nerve. (L. Testut.)

To face p. 472.

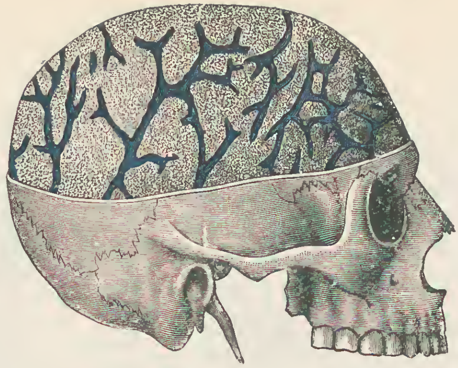

FIG. 354.—VEINS OF THE DIPLOE. The outer table of the cranial wall has been removed. (L. Testut.)

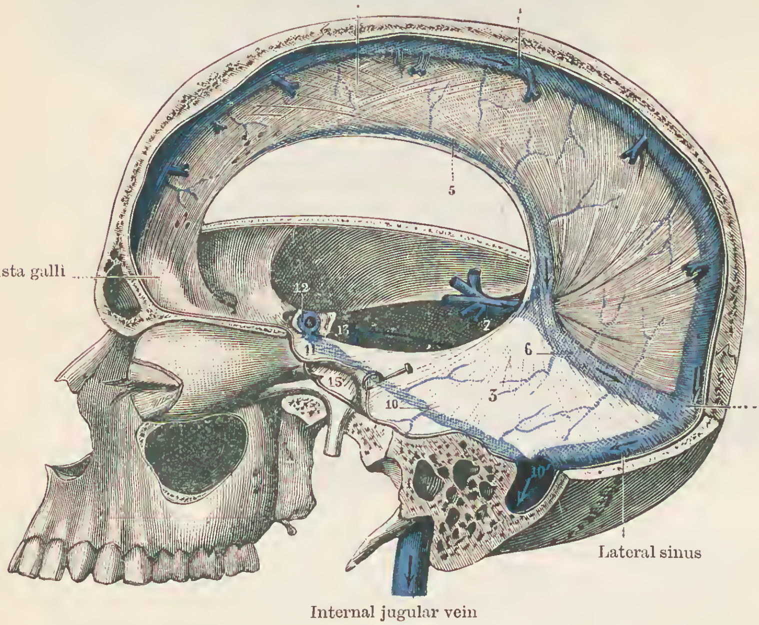

FIG. 355.—THE VENOUS SINUSES OF THE CRANIUM. 3, Tentorium; 5, inferior longitudinal sinus; 6, straight sinus: 7, vena magna Galeni; 10, superior petrosal sinus; 10′, place of junction of superior petrosal with lateral sinus; 11, cavernous sinus; 12, circular sinus; 15, Gasserian ganglion. (L. Testut.)

To face p. 473.

The *pterygoid plexus* surrounds the pterygoid muscles. It is formed of vessels which correspond to the branches of the internal maxillary artery, viz., middle meningeal, inferior dental, tympanic, pterygoid, deep temporal, superior dental, palatine, spheno-palatine, and infraorbital veins. It communicates above with the ophthalmic veins and the cavernous sinus, anteriorly with the facial vein, and below with the pharyngeal plexus.

The Veins of the Cerebrum.

The veins of the cerebrum are divided into superficial and deep sets. Some of the superficial veins of the inner surface of the hemisphere enter the trunks of the deep veins.

The superficial veins. Those from the *superior* part of the hemispheres, ten to twelve in number on each side, pass to the superior longitudinal

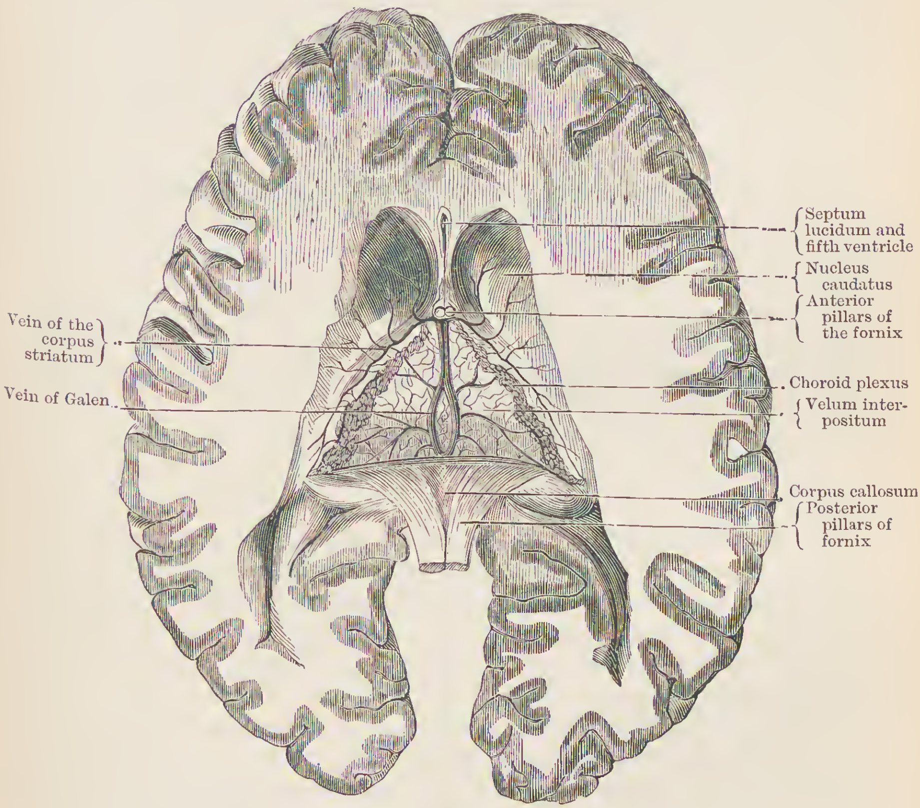

Fig. 356.—The Velum Interpositum and the Veins of Galen. (Beaunis.)

sinus; those from the *inferior* regions pass to the cavernous, superior petrosal, and lateral sinuses. Among the superficial veins, one, the *superficial Sylvian* or *middle cerebral vein*, of comparatively large size, overlying the Sylvian

fissure, enters the cavernous sinus anteriorly, and is connected posteriorly, through *superior* and *posterior anastomotic veins*, with the superior longitudinal and lateral sinuses respectively. The superficial cerebral veins anastomose freely with one another.

The **deep cerebral veins** enter the *veins of Galen*, two trunks which run backwards side by side between the layers of the velum interpositum, and eventually join with one another to form the *vena magna Galeni*, a short stem which enters the straight sinus. Each vein of Galen (Fig. 356) is formed in the neighbourhood of the foramen of Monro by the junction of two vessels, namely, (*a*) *the choroid vein*, a vessel which ascends and passes forwards in the choroid plexus of the lateral ventricle, and (*b*) the *vein of the corpus striatum*, which runs forwards in the groove between the optic thalamus and corpus striatum, receiving branches from both. Passing backwards the veins of Galen are joined by branches from the optic thalamus, the choroid plexus of the third ventricle, the corpus callosum, and the corpora quadrigemina. Near its termination each vein receives a large branch, the *basilar vein*, which, commencing in front near the anterior perforated space by the junction of some *anterior cerebral veins*, from the under surface of the orbital region, with the *deep Sylvian vein*, from the island of Reil, runs backwards, receiving on its way inferior veins of the corpus striatum, emerging from the anterior perforated spot, and a number of tributaries from the region of the tuber cinereum, from the inner surface of the parietal and occipital lobes, and from the mid-brain. Some superior cerebellar veins join the vena magna Galeni.

Cerebellar veins. From the upper surface of the cerebellum branches pass to the great vein of Galen, and to the straight, lateral, and superior petrosal sinuses; the branches from the under surface pass to the lateral, inferior petrosal, and occipital sinuses.

The Veins of the Orbit.

The **common ophthalmic vein** (Fig. 357) is a short trunk which commences in the posterior part of the orbit, being formed by the union of the superior and inferior ophthalmic veins; it passes backwards between the heads of the external rectus muscle, below the entering nerves, and through the inner part of the sphenoidal fissure, to terminate in the anterior extremity of the cavernous sinus.

The *superior ophthalmic* vein commences in front in connection with the supraorbital, frontal, and angular veins, and passes backwards, crossing above the optic nerve in front of the ophthalmic artery, receiving as it goes the upper muscular, anterior and posterior ethmoidal, lachrymal, anterior ciliary, upper posterior ciliary veins, and the central vein of the retina.

The *inferior ophthalmic vein*, taking origin from the union of some of the lower muscular veins with the lower posterior ciliary veins, passes

backwards along the floor of the orbit, and communicates freely with the pterygoid plexus, in which it sometimes ends.

The tributaries of the ophthalmic veins correspond to the branches of the artery. The veins from the eyeball are the anterior and posterior ciliary veins. The *anterior ciliary veins* correspond to and accompany the anterior ciliary arteries. The *posterior ciliary veins* are four in number, and emerge from the sclerotic, a little behind the middle of the globe.

The Veins of the Diploe.

The veins of the diploe (Fig. 354) run in the cancellated bony tissue which lies between the outer and inner tables of the skull. They may be divided into frontal, parietal, and occipital sets. The *frontal veins* open partly into the supraorbital vein, and partly into the cavernous sinus. The *parietal veins* partly end in the deep temporal veins, and partly in the superior petrosal and lateral sinuses. The *occipital veins* terminate in the lateral sinus, and in the veins which ramify externally on the surface of the occipital region of the skull.

The Venous Sinuses of the Cranium.

The venous sinuses are channels within the substance of the dura mater, possessing a delicate lining membrane continuous with that of the veins. They communicate at certain spots with the external veins by small perforating vessels which are sometimes called "the emissary veins of Santorini." They receive the blood from the cerebrum and cerebellum, the orbit and eye-ball, and to a small extent from the meninges and diploe. They terminate in the internal jugular vein.

The **superior longitudinal sinus** (Fig. 355), triangular in section with the apex downwards, commences at the crista galli, and, gradually increasing in size, extends backwards along the middle line to the internal occipital protuberance, where, turning sharply to the right, it becomes continuous with the right lateral sinus. Its lumen is at many places interrupted by transverse fibrous bands (the cords of Willis), and Pacchionian bodies here and there project into it. It receives the superior cerebral veins, most of which pass into it from behind forwards, a direction opposed to that of the current of blood within it. Some meningeal branches from the falx likewise enter it. In many cases it communicates through the parietal foramen with the veins of the scalp, and in early life constantly through the foramen caecum with those of the nose. Occasionally it terminates in the left lateral sinus.

The **inferior longitudinal sinus** or **vein** (Fig. 355), a slender channel, receiving usually some branches from the falx, runs backwards in the free margin of the falx and terminates in the straight sinus.

The **straight sinus** (Fig. 355), triangular in section with the apex upwards,

runs backwards and downwards on the surface of the tentorium along the line of attachment of the falx. It commences in front at the junction of the inferior longitudinal sinus with the vena magna Galeni from the velum interpositum, and terminates behind, usually in the left lateral sinus, occasionally in that of the right side. It receives lateral branches from the upper surface of the cerebellum and from the tentorium.

The **lateral sinuses** (Figs. 352, 357) commence at the internal occipital protuberance, where they are connected transversely across the middle line, a confluence, the *torcular Herophili*, being formed between them and the terminations of the superior longitudinal and straight sinuses. Each passes outwards on the occipital bone as far as the inferior angle of the parietal, crossing which it is slightly arched upwards; it then bends sharply, and is directed downwards and inwards on the inner surface of the mastoid; it finally turns forward on the jugular process of the occipital bone to the jugular foramen, in the posterior part of which it becomes continuous with the internal jugular vein. It receives, just as it is bending downwards, the superior petrosal sinus; a little lower, the mastoid perforating vein which connects it with the occipital vein enters it; near its termination it is usually connected with the occipital sinus, and occasionally through the posterior condylar foramen with the suboccipital plexus. Lateral branches pass to it from the temporal lobe of the brain, the cerebellum, the medulla and pons, and from the posterior veins of the diploe. The transverse portion of each sinus runs along the attachment of the tentorium. The sinus of the right side, continued, usually, from the superior longitudinal sinus, is commonly larger than that of the left, which in most cases carries the blood of the straight sinus. The position of the sinus may be marked externally by a line drawn horizontally from the external occipital protuberance to the base of the mastoid process, and then bent downwards towards the tip of the process. In some cases a small sinus, the *petro-squamous sinus*, passes forwards from the lateral sinus along the line between the petrous and squamous portions of the temporal bone. It represents the terminal portion of the lateral sinus of the very early embryo, in which the blood from the cranial cavity passed through a foramen in front of the ear to the primitive jugular (external jugular) vein.

The **occipital sinus** (Fig. 357), a small channel, ascends to the torcular Herophili along the line of attachment of the falx cerebelli. It commences at the sides of the foramen magnum and is usually connected with one or both lateral sinuses. It communicates with the posterior intraspinal veins, and frequently, through the anterior condylar foramen, with the vertebral and anterior spinal veins.

The **cavernous sinuses** (Fig. 357) lie on each side of the body of the sphenoid bone, extending backwards from the sphenoidal fissure to the apex of the petrous bone. Their cavities are broken up into a number of intercommunicating spaces by delicate interlacing bands. They communicate, across the middle line, with one another by branches in front of,

behind, and occasionally also below the pituitary body, which together are named the *circular sinus*; and a small lateral projection of each, outwards beneath the small wing of the sphenoid, is sometimes named the *spheno-parietal sinus.* They receive the ophthalmic veins, some lateral tributaries from the frontal lobes, the superficial Sylvian veins, and some anterior meningeal veins, and their blood passes backwards in the superior and inferior petrosal sinuses. Each cavernous sinus communicates with the pterygoid plexus of its own side through the ophthalmic vein and through the slender Vesalian vein, which passes through a small foramen in the great wing of the sphenoid. Communicating branches also pass through the foramen lacerum medium and the carotid foramen to the pharyngeal plexus and the internal jugular vein. In the outer wall of the sinus the third and fourth nerves, and the ophthalmic division of the fifth nerve run forwards; and through the sinus, covered only by the thin lining membrane, the internal carotid artery and the sixth nerve pass.

The **superior petrosal sinuses** (Fig. 357), narrow channels, run backwards from the posterior extremities of the cavernous sinuses to the lateral sinuses. Each sinus lies on the upper border of the petrous bone, along the attachment of the tentorium, and receives veins from the tympanum, the temporal lobe of the brain, and the cerebellum.

The **inferior petrosal sinuses** (Fig. 357), shorter but of greater diameter than the superior, pass backwards from the extremities of the cavernous sinuses. Each runs along the posterior margin of the petrous bone, and passes through the anterior compartment of the jugular foramen to end in the bulb of the internal jugular vein. Between the sinuses of opposite sides there stretches a plexus of intercommunicating veins which lies upon the basilar process, and is connected with the anterior intraspinal veins; it receives the name of *basilar or transverse sinus.* The inferior petrosal sinus receives veins from the internal ear, the medulla and pons, and the cerebellum.

The communications between the intracranial and extracranial venous channels. The *cavernous sinus* is placed in communication by the upper division of the ophthalmic vein with the frontal, nasal, and angular veins, and by the lower division of the ophthalmic vein, the Vesalian vein, and one or two small veins traversing the foramen ovale, with the pterygoid plexus. It is further connected with the pharyngeal plexus by branches which pass through the foramen lacerum medium, and with the internal jugular vein by a minute plexus surrounding the internal carotid artery. The *lateral sinus* communicates, by means of the mastoid vein, with the occipital or posterior auricular vein, and occasionally also by a vein which occupies the posterior condylar foramen it is connected with the vertebral veins. The *basilar sinus* communicates with the anterior intraspinal veins; the *occipital sinus* is connected with the posterior intraspinal veins, and through the anterior condylar foramen with the vertebral and extraspinal veins. Occasionally a minute vein passes

from the *torcular Herophili* to one of the tributaries of the occipital vein. The *superior longitudinal sinus* communicates in many cases through the parietal foramen with the radicles of the temporal vein, and in the child through the foramen caecum with the veins of the nose.

THE SPINAL VEINS.

The spinal veins form a complicated plexus of vessels which may be subdivided into separate groups as follows, viz., the veins of the spinal cord, the veins of the vertebral bodies, the anterior and posterior extra spinal veins, and the anterior and posterior intraspinal veins.

The **veins of the spinal cord** ramify in the pia mater, and are disposed as anterior, lateral, and posterior longitudinal trunks, and a network of branches communicating above with the veins of the medulla. Laterally branches pass outwards on the nerve roots, and are connected with offsets of the intraspinal veins.

The **veins of the vertebral bodies** (Fig. 358) are accompanied by minute arteries, and ramify in the cancellous tissue of the bones; they communicate in front with the anterior extraspinal veins, and behind empty themselves into the anterior intraspinal veins.

The **anterior extraspinal veins** (Fig. 358), best developed in the neck, form a plexus of small branches on the anterior surface of the spinal column. They communicate below with the plexus in front of the sacrum, and laterally are connected, according to the region, with the vertebral, dorsal, or lumbar veins.

The **posterior extraspinal veins** form a plexus which rests upon the laminae and the articular and spinous processes, and receives deep and superficial tributaries from the back. Frequently the superficial veins of the back are connected with one another by a slender median anastomosing vessel. The plexus communicates anteriorly, by branches which pierce the ligamenta subflava, with the intraspinal plexus, and laterally, according to the region, with the vertebral, dorsal, lumbar, or lateral sacral veins.

The **anterior intraspinal veins** (Fig. 358) are two long trunks running the whole length of the canal, placed one on each side of the posterior common ligament of the bodies. Opposite the bodies of the vertebrae each trunk is somewhat dilated, and communicates with its fellow by a transverse branch which crosses in front of the posterior common ligament, and receives the veins of the vertebral body. Above, they are connected with the basilar plexus of veins; lateral offsets accompany the nerves in the intervertebral foramina.

The **posterior intraspinal veins**, one on each side of the middle line, lie in front of the laminae, and are connected with one another by numerous transverse branches. From behind they receive the perforating branches of the posterior extraspinal plexus. Above they communicate with the occipital sinuses, and, along with the anterior intraspinal veins

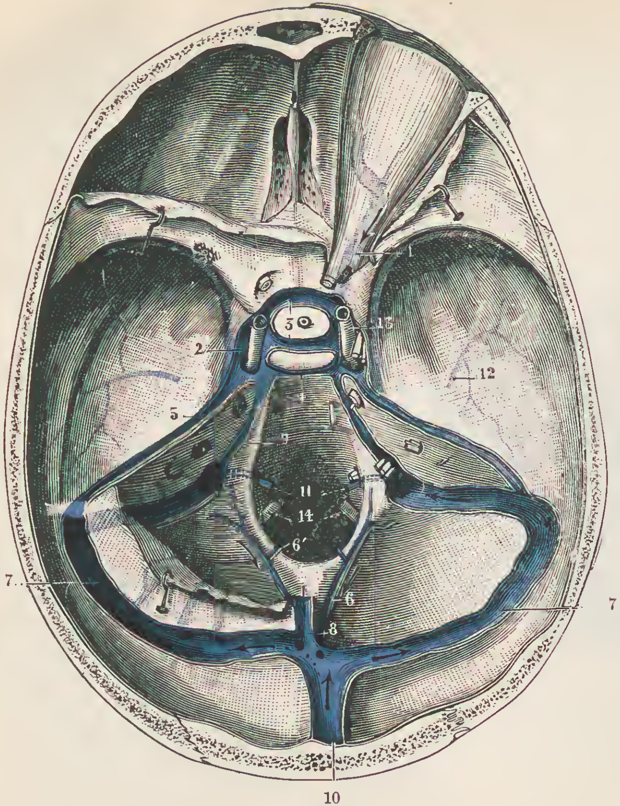

Fig. 357.—The Venous Sinuses of the Base of the Skull. 1, Ophthalmic vein; 2, cavernous sinus; 3, circular sinus; 4, transverse or basilar sinus; 5, superior petrosal sinus; 6, occipital sinus; 7, lateral sinus; 8, straight sinus; 9, inferior petrosal sinus; 10, superior longitudinal sinus; 11, anterior condylar veins; 12, middle meningeal vein; 13, internal carotid artery; 14, vertebral arteries. (L. Testut.)

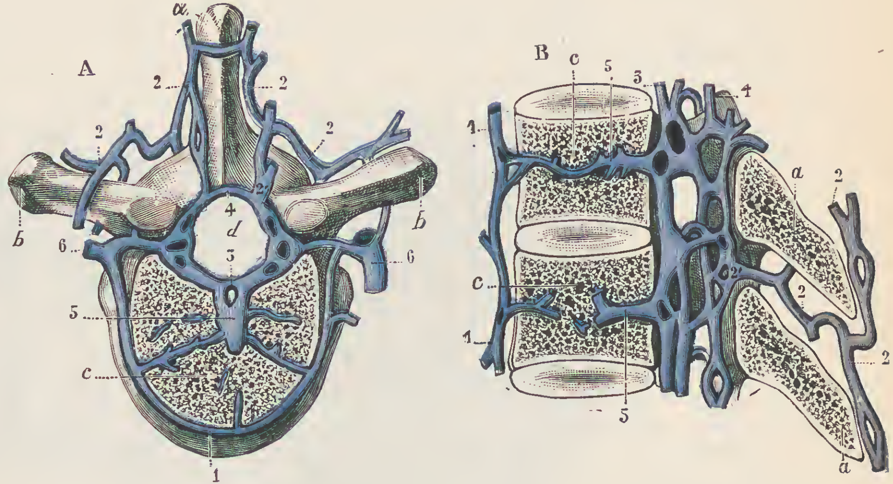

Fig. 358.—A, Horizontal section of the spinal cord in the lower dorsal region, showing the spinal veins; B, vertical antero-posterior section. *a*, Spinous process; *b*, transverse process; *c*, vertebral body; *d*, spinal canal: 1, anterior extraspinal veins; 2, posterior extraspinal veins; 2′, connecting branch between intraspinal and extraspinal veins; 3, anterior intraspinal veins; 4, posterior intraspinal veins; 5, veins of the vertebral bodies; 6, intercostal vein. (L. Testut.)

To face p. 478.

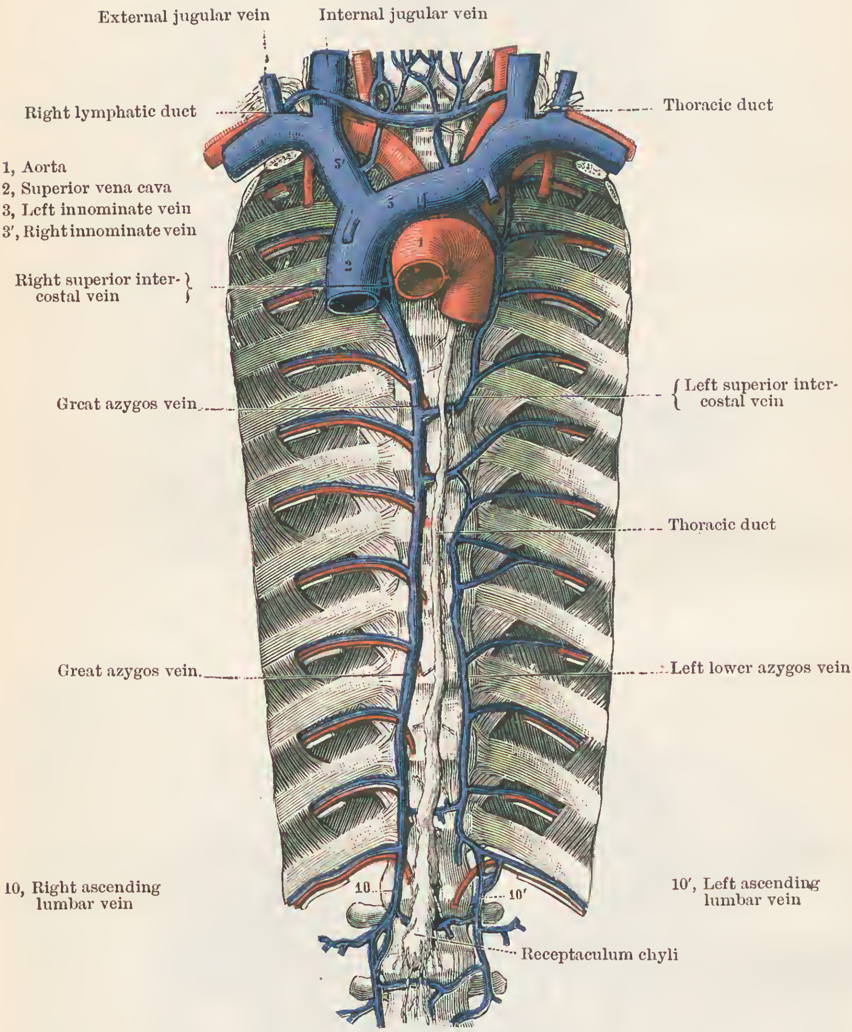

FIG. 359.—THE INTERCOSTAL VEINS AND THE AZYGOS VEINS. (L. Testut.)

and the basilar plexus, take part in forming a venous ring at the foramen magnum. Laterally they are connected by their branches with the veins of the cord and with offsets from the anterior intraspinal vessels. The intraspinal veins lie between the dura mater and the walls of the spinal canal.

THE VEINS OF THE THORAX.

The **internal mammary veins** (Fig. 351) are two trunks which lie one on each side of the artery. In the first or second intercostal space they join with one another to form a single vessel, which is placed by the inner side of the artery, and falls into the innominate vein of its own side.

The **intercostal veins** (Fig. 359) are eleven in number on each side. Each vein lies above its companion artery, and receives tributaries corresponding to its branches. With the exception of one or two of the higher vessels on each side, the intercostal veins, in their passage inwards, cross behind the cords of the sympathetic. *On the right side* the first intercostal vein ascends by the side of the superior intercostal artery, and terminates in the vertebral vein. The veins of the second, third, and fourth spaces usually join with one another to form a descending trunk, the *right superior intercostal vein*, which falls into the vena azygos major as it is arching over the root of the lung. The lower veins terminate separately in the great azygos vein. *On the left side* the first intercostal vein, like that of the right side, ascends to the vertebral vein. The second, third, fourth, and frequently one or two more, fall into an ascending trunk, the *left superior intercostal vein* which crosses the arch of the aorta, and joins the left innominate vein. Still lower, two or three veins cross the middle line and enter the great azygos vein either separately or by a common trunk, the left upper or third azygos vein, which is frequently connected with the lower end of the left superior intercostal vein. The lowest three or four veins of the left side open into the left lower or smaller azygos vein.

The **azygos veins** (Fig. 359). The **great or right azygos vein** commences in the abdomen, as the ascending lumbar vein, a vessel which ascends in front of the transverse processes and connects the successive lumbar veins with one another, and which, in addition, is usually connected with the common iliac vein, the inferior cava, and the renal vein by branches, any one of which may become enlarged and appear as the root of the azygos vein. The great azygos vein ascends through the aortic opening, and continues its course upwards on the vertebral column lying to the right of the aorta and the thoracic duct. About the level of the fifth dorsal vertebra it leaves the spine and arches over the root of the right lung to fall into the superior vena cava. It receives the first lumbar vein of the right side and all the right intercostal veins except the first, the right bronchial vein and some oesophageal branches, and, in addition, through the left azygos veins, a number of the intercostal veins of the left side.

The **left lower** or **smaller azygos vein** takes origin in the abdomen in a manner similar to that of the great azygos. It passes through the left crus, and ascends upon the spine as far as the seventh or eighth dorsal vertebra, where it crosses behind the aorta and thoracic duct to fall into the great azygos vein. It receives some oesophageal branches, the first left lumbar, and three or four of the lower intercostal veins of its own side.

The **left upper azygos vein** is formed by the junction of two or three of the left intercostal veins belonging to the middle of the series, and frequently communicates above with the left superior intercostal vein. It falls into the great azygos or, sometimes, into the left lower azygos vein, but is very variable, and is often absent altogether.

The **bronchial veins** accompany the corresponding arteries; that of the right side terminates in the great azygos vein, that of the left falls into the left upper azygos, or the left superior intercostal vein.

THE VEINS OF THE ABDOMEN AND PELVIS.

The **inferior vena cava** (Figs. 336, 360) commences under cover of the right common iliac artery at the level of the upper margin of the body of the last lumbar vertebra; it ascends with a slight inclination forwards, pierces the diaphragm, entering at the same time the pericardial cavity, and immediately afterwards terminates, opposite the lower border of the eighth dorsal vertebra, in the right auricle of the heart. Before passing through the diaphragm it lies in a deep groove on the under surface of the liver, lower down it rests upon the right crus, still lower it lies by the right side of the aorta upon the vertebral column. On its deep surface the right lumbar, renal, suprarenal, and inferior phrenic arteries pass outwards; the solar plexus lies behind it; it is crossed superficially by the right spermatic artery, the mesentery, the duodenum and pancreas, and the portal vein. It is formed by the confluence of the two common iliac veins, and it receives as tributaries the lumbar, renal, inferior phrenic, and hepatic veins, and the right spermatic or ovarian, and right suprarenal.

The **lumbar veins** accompany the lumbar arteries. The highest vein on each side usually falls into the azygos vein, the lower ones into the inferior cava, those of the left side crossing behind the aorta. On the deep surface of the psoas muscle, in front of the transverse processes, a vertically running vessel, the *ascending lumbar vein*, connects the successive trunks, and is continued above into the azygos vein; it communicates frequently with the renal vein, the common iliac, and the inferior cava.

The **renal veins** (Fig. 360) fall into the inferior vena cava, and are placed in front of the renal arteries; that of the right side is a short trunk; that of the left, considerably longer, crosses in front of the aorta, and receives the left suprarenal and left spermatic veins, and occasionally the left inferior phrenic vein. Imperfect valves are found in the renal veins.

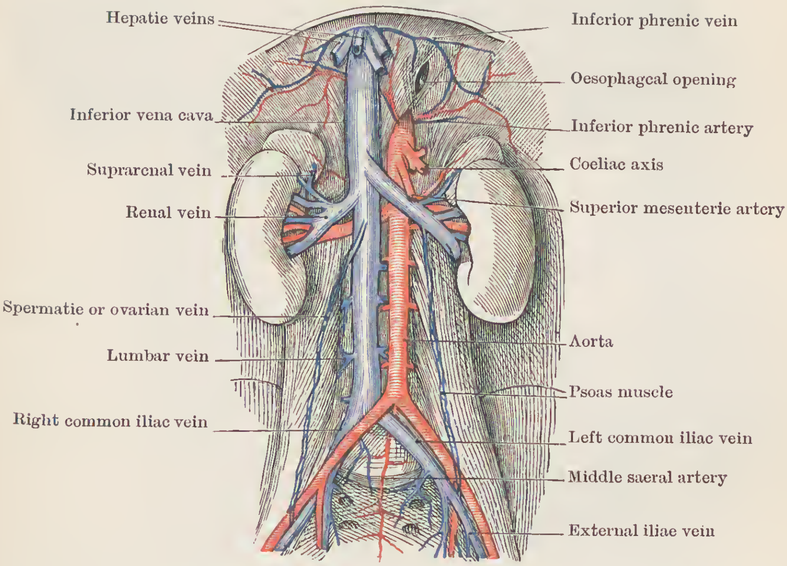

FIG. 360.—THE INFERIOR VENA CAVA AND THE ABDOMINAL AORTA. (C. Gegenbaur.)

To face p. 480.

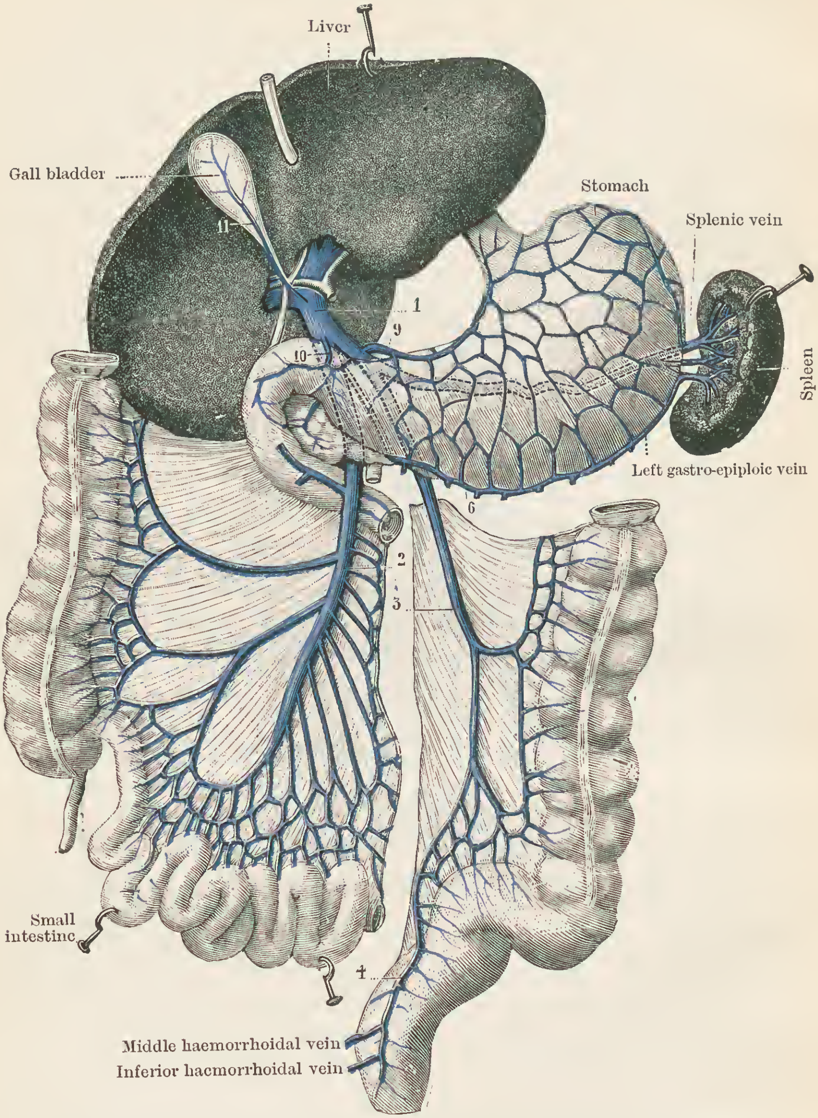

FIG. 361.—THE PORTAL SYSTEM. 1, Portal vein; 2, superior mesenteric vein; 3, inferior mesenteric vein; 4, superior haemorrhoidal vein; 6, right gastro-epiploic vein; 9, coronary vein of stomach; 10. pyloric vein; 11, cystic vein. (L. Testut.)

The **spermatic veins** ascend from the testicle, and are placed in front of the spermatic artery and vas deferens. They exhibit at first a plexiform arrangement (*pampiniform plexus*). Within the inguinal canal the plexus is reduced to two or three vessels which, higher up, join with one another and form a single vein. The vein of the right side enters the inferior cava; that of the left falls into the left renal vein.

The **ovarian veins** form a plexus (*ovarian or pampiniform plexus*) between the layers of the broad ligament, and communicate freely with the uterine veins. Higher up they behave like the spermatic veins. Valves are usually found at the terminations of the spermatic or ovarian veins, and imperfect valves are found in their branches.

The **suprarenal veins**, one on each side, terminate on the right side in the inferior cava, and on the left side in the left renal vein.

The **inferior phrenic veins** accompany the inferior phrenic arteries; the vein of the right side enters the inferior cava, that of the left falls into either the left renal or the inferior cava.

The **hepatic veins** open directly into the inferior vena cava, as two or three large trunks and a number of smaller ones. They have no valves, but, as they enter the inferior cava obliquely, the lower margin of each forms a semilunar projection.

The **common iliac veins** (Figs. 336, 360) are formed by the confluence of the external and internal iliac veins. Each vessel passes upwards and inwards from a point opposite the upper margin of the sacro-iliac articulation, and at the upper border of the fifth lumbar vertebra, a little to the right of the middle line, unites with its fellow. The vein of the right side ascends behind the right common iliac artery, that of the left side is placed to the right of the left common iliac artery, and at its termination lies behind the upper part of the right common iliac artery. The common iliac veins usually contain no valves. They receive as tributaries the *ilio-lumbar veins* which accompany the ilio-lumbar arteries, and that of the left side also receives the *middle sacral vein*, a vessel which is formed by the union with one another of the two venae comites of the middle sacral artery.

The **internal iliac vein** lies behind and to the inner side of the internal iliac artery, and extends from the neighbourhood of the upper margin of the great sacro-sciatic notch to the level of the upper part of the sacro-iliac articulation, where it unites with the external iliac vein. It contains no valves. It receives tributaries corresponding to all the branches of the internal iliac artery, except the ilio-lumbar, the vein accompanying which, in ordinary circumstances, terminates in the common iliac vein. By the free communication of the venous radicles which unite to form the tributaries of the internal iliac veins, several intercommunicating plexuses are formed in the pelvis.

The *anterior sacral plexus* is formed upon the front of the sacrum by the tributaries of the middle sacral and lateral sacral veins. It communicates with the spinal veins and with the haemorrhoidal plexus.

The *haemorrhoidal plexus* lies immediately under the mucous membrane of the lower part of the rectum, and communicates in front with the vaginal or prostatic plexus. The veins which pass from it are the superior haemorrhoidals of the portal system, the middle haemorrhoidals passing to the internal iliacs, and the inferior haemorrhoidals joining the pudics.

The *vaginal plexus* surrounds the lower part of the vagina; it receives branches from the vagina and from the uterus, but the latter veins have also a free connection with the pampiniform plexus, formed between the layers of the broad ligament by the ovarian veins.

The *vesical plexus* surrounds the whole bladder, lying under cover of the peritoneal coat. Vesical veins pass from it to the internal iliac veins; and it communicates below with the vaginal or prostatic plexus.

The *prostatic plexus* surrounds the base and sides of the prostate gland, and is covered by the sheath from the recto-vesical fascia; it communicates above with the vesical plexus, and receives from the front the dorsal vein of the penis.

The *dorsal vein of the penis*, a single median vessel, commences in a set of veins which form a circle round the base of the glans. It passes backwards along the dorsum of the organ, receiving both superficial and deep branches. At the base of the penis it gives off on each side a slender branch of communication to the pudic veins, and is then continued backwards through the triangular ligament to the prostatic plexus.

The internal pudic veins. Two small venae comites accompany the pudic artery and terminate in the internal iliac vein. They receive veins from the corpus cavernosum and the bulb, and the perineal and inferior haemorrhoidal veins.

The *obturator*, *sciatic*, and *gluteal veins* fall into the internal iliac vein.

The **external iliac vein** (Fig. 360) extends from the level of Poupart's ligament to a spot opposite the sacro-iliac articulation, where it unites with the internal iliac vein. Below it is internal to the artery; higher up it is internal and posterior to it. It usually contains one or two valves. It receives as tributaries the *deep epigastric* and *deep circumflex iliac veins*, vessels which accompany the similarly named arteries.

THE PORTAL SYSTEM OF VEINS.

The veins from the abdominal and pelvic portions of the intestinal canal and those from the spleen, pancreas, and gall bladder carry their blood to the portal vein, a vessel which enters the liver, and there ramifies like an artery, its capillaries, along with those of the hepatic artery, eventually opening into the hepatic veins. In the adult there are no valves in the portal vein nor in any of its tributaries.

The **portal vein** (Fig. 361), about three inches in length, commences at the confluence of the superior mesenteric and splenic veins, behind the

pancreas and immediately in front of the vena cava inferior, a little to the right of the middle line. It ascends behind the first part of the duodenum and enters the small omentum, between the folds of which, lying behind the hepatic artery and bile duct, it passes towards the transverse fissure of the liver. At its termination it becomes somewhat swollen, and divides into right and left branches, which pass to the respective lobes, that for the right being shorter and thicker than that destined for the left; the left branch, in addition, partly supplies the quadrate and Spigelian lobes. The left branch of the portal vein is connected posteriorly with a solid cord, the *remains of the ductus venosus*, and anteriorly with the round ligament of the liver, the *remains of the umbilical vein.* The right branch is joined by the *cystic vein.* The trunk of the portal vein receives *the coronary vein of the stomach* and, a little lower, the *pyloric vein*, both of which correspond to the similarly named arteries.

The **superior mesenteric vein** is the companion of the superior mesenteric artery, to the right and in front of which it is placed. In addition to branches which correspond to those of the artery it receives near its upper extremity the *right gastro-epiploic vein.* It crosses in front of the third part of the duodenum, and terminates behind the pancreas in the portal vein.

The **splenic vein** lies immediately below the splenic artery, and receives, in addition to branches which correspond to those of the artery, the inferior mesenteric vein, which, ascending from below, joins it near its termination in the portal vein.

The **inferior mesenteric vein** passes upwards, at first, on the left side of the inferior mesenteric artery; afterwards, ascending beyond the level of the place of origin of the artery, it is continued with an inward inclination behind the pancreas, and terminates in the splenic vein. Its branches correspond to those of the artery; those which are lowest in position, the *superior haemorrhoidal*, take origin in the *haemorrhoidal plexus*, where they freely communicate with the middle and inferior haemorrhoidal veins. The plexus lies immediately under the mucous membrane of the lower part of the rectum.

THE VEINS OF THE LIMBS.

The veins of the limbs are divided into two groups, *deep* and *superficial* in position, freely communicating with one another. They are all provided with valves, but these are more numerous in the deep than in the superficial veins, and in those of the lower than in those of the upper limb. The deep veins accompany the arteries, and, as a rule, need no detailed description; but the superficial veins have mostly no arteries corresponding to them, and form plexuses on the surface of the fascia, more particularly at the distal extremities of the limbs.

Veins of the Upper Limb.

The **superficial veins of the hand** (Fig. 362). Although in each finger a couple of minute venae comites accompany each digital artery, the greater part of the returning blood passes through the meshes of a subcutaneous plexus to a couple of superficial dorsal veins. Above the clefts of the fingers the dorsal vessels from the contiguous sides of the neighbouring digits unite with one another, and the resulting trunks, passing upwards, enter on the back of the hand a large irregularly disposed plexus. From the outer border of the plexus the radial vein is prolonged, and from the inner border the posterior ulnar vein takes origin, and to a slight extent also the anterior ulnar. A number of small veins from the palm of the hand and the thenar eminence converge to form the median vein; a few branches from the inner side of the palm join the anterior ulnar vein. Numerous small communicating branches connect the deep and superficial veins of the palm.

The **superficial radial vein** commences in the outer part of the dorsal plexus, and courses upwards along the outer border of the forearm, receiving numerous superficial tributaries. A little above the elbow, on the outer side of the biceps muscle, it unites with the median cephalic to form the cephalic vein. It communicates below with the deep veins of the palm, and higher up with the deep radial veins.

The **posterior superficial ulnar vein**, arising from the inner extremity of the dorsal plexus, passes upwards on the posterior aspect of the forearm, receiving numerous tributaries which communicate with those of the radial and anterior ulnar veins. Below the elbow it is joined by the anterior ulnar vein, and a little above the level of the joint it unites, on the inner side of the biceps muscle, with the median basilic to form the basilic vein. A considerable communicating branch passes between the lower part of the vein and the deep ulnar veins.

The **anterior superficial ulnar vein**, smaller than the posterior, which it joins a little below the elbow, commences near the wrist, and ascends along the ulnar border of the forearm. Its tributaries communicate freely with those of the veins on either side of it.

The **superficial median vein** (Fig. 363) ascends along the front of the forearm. At the hollow of the elbow it is joined by the *deep median vein*, a large communicating branch from the ulnar and radial venae comites. The resulting trunk immediately divides into the median cephalic and median basilic veins. The tributaries of the median vein are derived from the palm of the hand and the front of the forearm, and communicate freely with those of the neighbouring superficial trunks.

The **median cephalic vein** passes upwards and outwards to join the superficial radial vein. The **median basilic vein** passes upwards and inwards to join the posterior superficial ulnar vein; it rests behind on the semilunar fascia of the biceps, which separates it from the brachial

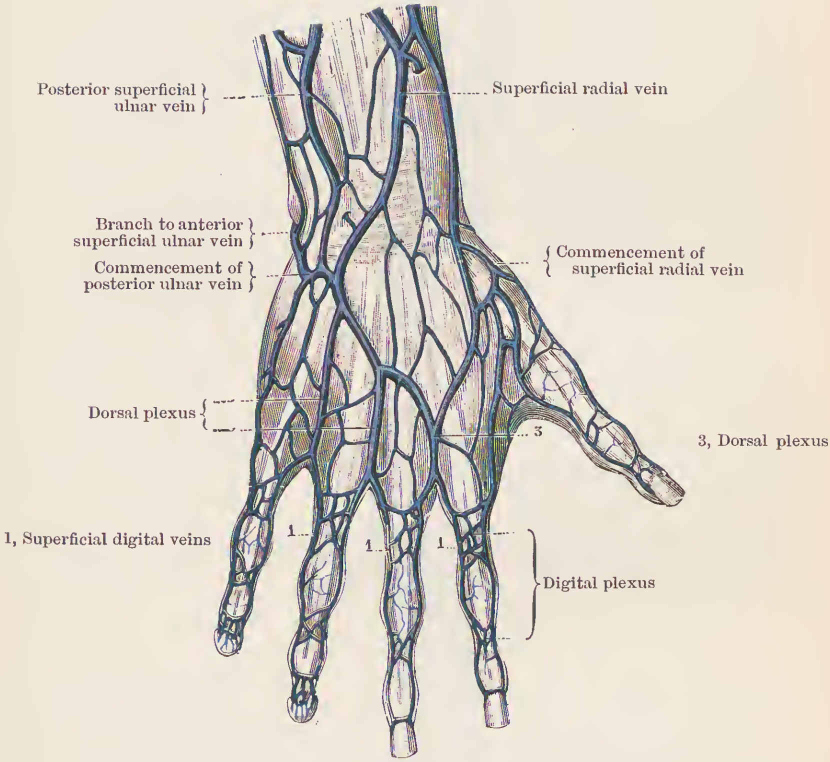

Fig. 362.—The Superficial Veins of the Back of the Hand. (L. Testut.)

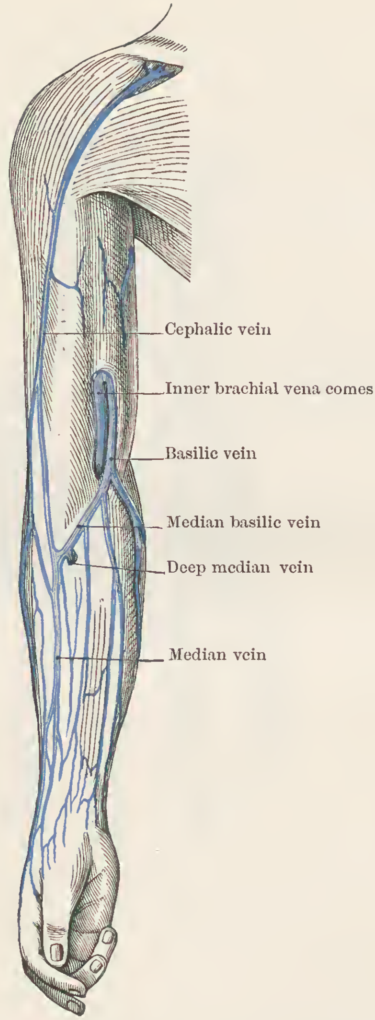

FIG. 363.—THE SUPERFICIAL VEINS OF THE UPPER LIMB. (C. Gegenbaur.)

To face p. 485.

artery. Although the superficial trunks of the arm, on account of the free anastomoses between their tributaries, are subject to many variations, yet a considerable vein will almost constantly be found in the position of the median basilic. For this reason, despite its proximity to the main artery, the median basilic vein was in the past, when blood-letting was a more fashionable procedure than it is now, usually selected for the operation of venesection.

The **basilic vein** (Fig. 363) ascends on the inner side of the biceps; about the middle of the arm, after passing through the deep fascia, it terminates by joining the inner of the two brachial venae comites.

The **cephalic vein** (Fig. 363) ascends at first on the outer side of the biceps, and afterwards in the groove between the deltoid and pectoralis major muscles to a spot a little below the clavicle, where, passing deeply, it crosses the first part of the axillary artery, pierces the costo-coracoid membrane, and terminates in the axillary vein. Occasionally the cephalic vein is prolonged over the clavicle to terminate in the external jugular or subclavian vein, and even when the termination is normal, a considerable branch is sometimes found passing upwards in front of the collar bone. A vessel in this position might be divided by the surgeon in making the cutaneous incision in the operation for ligature of the third part of the subclavian artery. Both basilic and cephalic veins receive small tributaries from the arm.

The deep veins of the upper limb. Each artery below the axillary is accompanied by two venae comites. The **axillary vein** ascends by the inner side of the axillary artery; in addition to the tributaries, which correspond to the branches of the artery, it receives the cephalic vein; it is frequently double in the lower part of the axilla, and occasionally in its whole course.

Veins of the Lower Limb.

The **superficial digital veins** pass backwards to a venous arch on the dorsum of the foot, those of the plantar surface ascending behind the clefts of the toes to join the larger dorsal vessels. The *superficial veins of the sole* are small but numerous; the anterior vessels reach the dorsum along with the plantar digital veins, the posterior turn round the sides of the foot to join the dorsal arch. *The dorsal venous arch*, of considerable size but very irregular in disposition, lies upon the instep; it receives digital, dorsal, and plantar tributaries, and posteriorly is continued into the external and internal saphenous veins. Between the clefts of the toes, on the dorsum, and at the sides of the foot there are numerous communications between the deep and superficial veins.

The **external saphenous vein** (Fig. 365), from the outer side of the dorsal arch, passes behind the external malleolus and ascends with an inward inclination upon the back of the leg to the lower part of the popliteal space, where, after perforating the deep fascia, it enters the popliteal vein.

It receives numerous superficial tributaries from the outer side of the foot, and from the outer and posterior region of the leg, and a number of communicating branches from the deep veins. Near its termination a communicating branch, sometimes so enlarged as to form the main continuation of the vein, ascends on the back of the thigh to join the internal saphenous vein.

The **internal saphenous vein** (Figs. 364, 371), from the inner extremity of the dorsal arch, passes in front of the internal malleolus, and ascends along the inner side of the leg; it bends backwards behind the inner condyle of the femur, and, finally, passes upwards upon the front of the thigh as far as the lower part of the saphenous opening where, about an inch and a half from Poupart's ligament, it falls into the femoral vein. It receives communicating branches from the plantar veins, the anterior and posterior tibial veins, and the deep veins of the thigh. Its tributaries are derived from the inner side of the foot, the inner and anterior region of the leg, the thigh, and the lower part of the abdominal wall. Very frequently a vessel of considerable size joins it near its termination, ascending for some distance in front of the femoral artery in the lower part of Scarpa's triangle.

Deep veins of the lower limb. With the exception of the femoral, the deep femoral, and the popliteal, all the arteries of the lower limb are accompanied by two companion veins. The **popliteal vein** is formed at the lower border of the popliteus muscle by the union with one another of the venae comites of the anterior and posterior tibial arteries. At the lower part of the space the vein is internal to the artery, but as it ascends it crosses the artery posteriorly and becomes a little external to it above. Frequently the popliteal vein is double in the lower part of the space, and occasionally in its whole course.

The **femoral vein**, in Hunter's canal, lies behind and a little external to the artery; at the apex of Scarpa's triangle it is posterior to the artery; higher up it gains the inner side of the artery, and in this position passes behind Poupart's ligament to be continued into the external iliac vein. In addition to tributaries which correspond to the branches of the artery, it receives the internal saphenous vein. The superficial circumflex iliac, superficial epigastric, and superficial pudic veins join the internal saphenous vein. The **deep femoral vein** ascends in front of the deep femoral artery, and falls into the femoral vein in the upper part of Scarpa's triangle.

The Development of the Heart.

The heart in man, and in mammals generally, makes its first appearance in the form of two tubes hollowed out of the splanchnic mesoblast on the ventral aspect of the alimentary canal, in the region of the head. Each tube is formed of a somewhat thickened outer wall of mesoblastic tissue, which becomes the muscular wall of the heart, and a delicate endo-

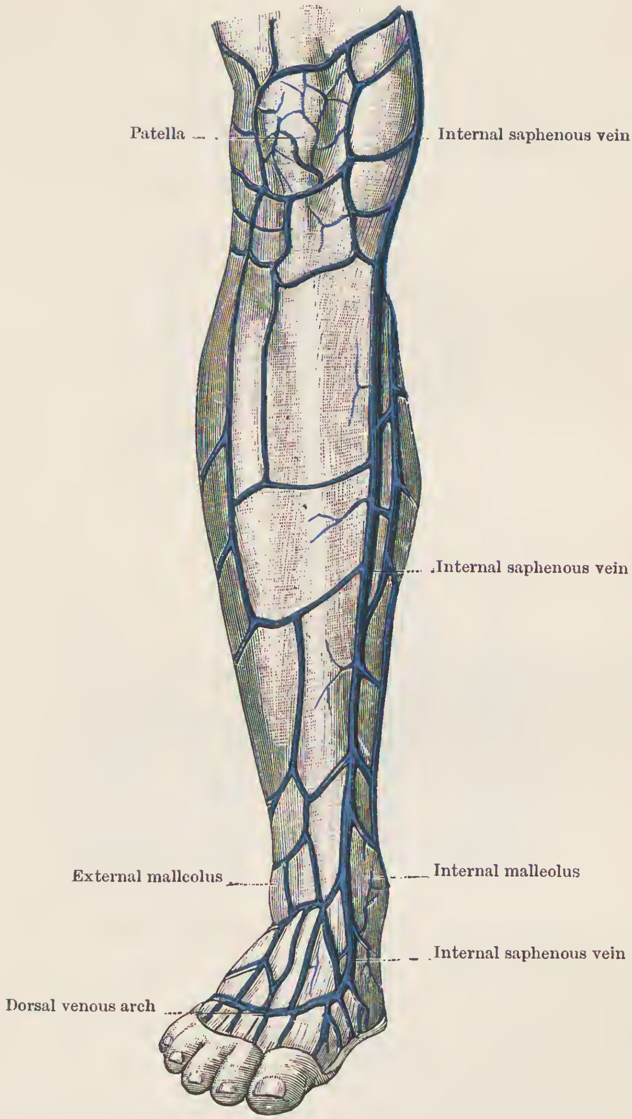

FIG. 364.—THE SUPERFICIAL VEINS OF THE LEG AND FOOT, from the front.

To face p. 486.

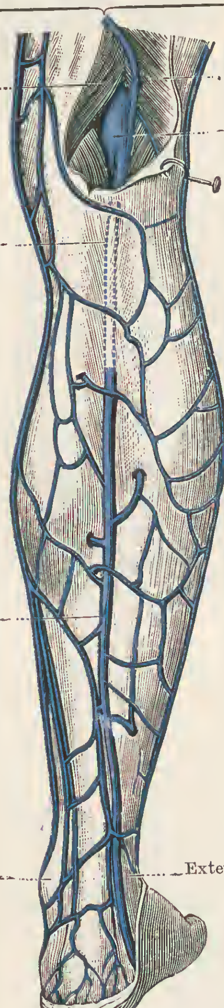

Fig. 365.—The Superficial Veins of the Back of the Leg. (L. Testut.)

To face p. 487.

thelial layer. When the ventral closure of the alimentary canal takes place, the tubes of opposite sides are brought into contact, and coalesce to form a mesial tube. The upper end of the tube is continuous with two arterial vessels which, forming the first pair of arterial arches, take a dorsal direction on the sides of the alimentary canal, and are continued downwards as the primitive aortae. The lower end of the tube is continuous with the two vitelline veins which bring back the blood from the surface of the yelk sac. In elasmobranch fishes and amphibia, the heart does not begin to develop until after the splanchnic walls have met ventrally, and makes its appearance from the first as a single tube; in birds the tube is at first single

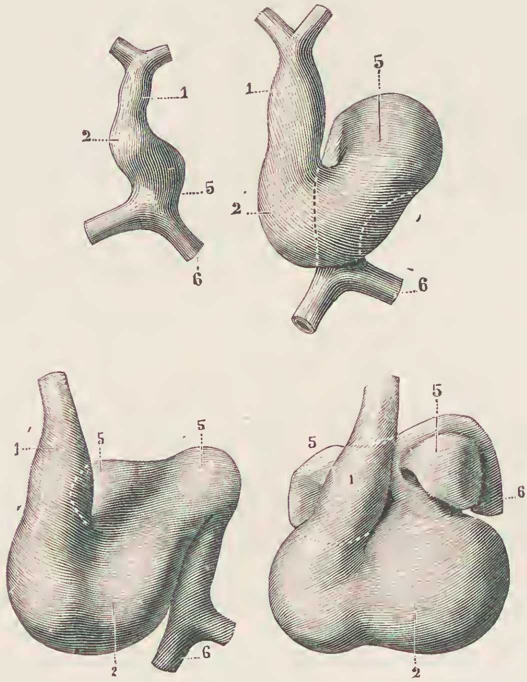

FIG. 366.—FOUR SUCCESSIVE STAGES IN THE DEVELOPMENT OF THE HEART. 1, Arterial bulb; 2, ventricle; 5, auricular portion; 6, veins entering the sinus venosus. (L. Testut.)

in front, but double behind. After the fusion has taken place the tube becomes divided by slight constrictions into four portions; of these the one nearest the head, the *bulbus arteriosus*, becomes the basal portion of the pulmonary artery and aorta, the next is the ventricular portion of the heart, the next the auricular, and the last forms the *sinus venosus*, a dilatation which at first receives all the veins, and afterwards becomes absorbed into the right auricle. While the successive portions are becoming differentiated from one another, the whole organ, growing more rapidly than the upper part of the body, and its arterial end being pushed away from the head, becomes bent upon itself. The curvature is at first S-shaped, the cephalic portion being bent to the right, the succeeding

portion to the left. Later, the curve is increased to a loop with the venous end dorsal to the arterial bulb, while the whole loop, projecting at the apex, is devoted to the ventricular part.

By the subsequent changes the cavity of the heart is divided into right and left portions, and the orifices become guarded by valves. Although in passing from the lower to the higher forms of vertebrate life it is the auricular portion which is first subdivided, yet in the course of the development of the mammalian heart it is the ventricular septum which first makes its appearance. The ventricular septum commences at the apex and extends both towards the auricle and the arterial bulb; afterwards it becomes continuous with the septa which divide the bulb and the auricle into right and left portions; but the junction does not take place at once, and for some time during foetal life, and occasionally as an abnormality in the adult, there is left a passage over the border of the ventricular septum from one side of the heart to the other. The walls of the ventricle early become muscular, and the cavity is at first comparatively small, being encroached upon by projecting muscular bands which have a reticulated arrangement, a condition which continues to a much greater extent through life in forms lower than birds.

The sinus venosus receives, in addition to the vitelline veins, the umbilical veins and the right and left ducts of Cuvier; and a little later the inferior vena cava joins the common orifice of the vitelline and umbilical veins. The opening of the sinus becomes shifted to the right portion of the common cavity, and is narrowed to a slit-like aperture guarded by prominent valvular folds. Eventually the sinus itself becomes absorbed into the right auricle, its anterior limit in the adult being marked by the sulcus terminalis of His. The right valvular fold of its orifice becomes the Eustachian valve at the opening of the inferior vena cava; the right duct of Cuvier persists as the superior cava, while the left undergoes atrophy, the portion of the sinus venosus into which it opened forming the coronary sinus.

The common auriculo-ventricular aperture, at first transversely elongated, becomes divided into two by endocardial thickenings which, projecting from its anterior and posterior lips, eventually join one another, and fuse likewise with the ventricular septum. The connective tissue of these thickenings forms the greater part of the membranous portion of the ventricular septum. From these thickenings the septal valves of the orifices are also formed. The lateral valves take origin by a slight folding in of the wall of the heart in the region between auricles and ventricles, and are at first largely formed of muscular tissue, which, however, afterwards almost entirely disappears. The exact method of the development of the auricular septum is still a subject of controversy. It grows from the upper part of the cavity, and descends to the left of the venous openings to become connected with the endocardial thickenings which subdivide the auriculo-ventricular orifice, and through them with

the ventricular septum. In the back part of the septum, an aperture, which forms the foramen ovale, is at first left, but becomes subsequently closed by a second septum. The left auricle becomes connected with the pulmonary veins in a manner which has not yet been accurately determined. The auricular appendices appear very early as ventral projections from each side of the common auricle.

The arterial bulb is divided into two stems by a septum which starts between the fourth and fifth arterial arches as two folds, one from each side of the vessel; these gradually meet one another, and are continued backwards in a spiral manner to join the ventricular septum. The channels which result from this division are ultimately completely separated and become the basal portions of the aorta and pulmonary artery. At the ventricular orifice of the bulb the segments of the valves are formed by endocardial projections. Before the common arterial orifice is subdivided there are four endocardial projections or cushions at its base; the right and left cushions increasing in size meet one another and, becoming continuous with the septum, subdivide the orifice into two, each of which presents three endocardial projections.

The heart is at first situated in the region of the head, but during development it is gradually shifted downwards until it assumes its permanent position in the thorax.

The Development of the Arteries.

In early embryonic life the bulbus arteriosus divides into two vessels which pass towards the head on the ventral aspect of the alimentary canal; springing from these the branchial arteries, forming a system of arterial arches, lie in series on the right and left sides of the alimentary canal, and fall into a couple of dorsal trunks which at first separately run the whole length of the body, but afterwards join with one another in the region below the heart and form there a single mesial vessel, the dorsal aorta. In fishes and amphibia, the arterial arches are connected with the gills; but in the higher forms, in which gills are never developed, the arterial arches pass dorsally at first in the successive branchial processes, and eventually partly disappear and partly give rise to the permanent vessels. There are five arches on each side in the embryos of all forms higher in the scale than the amphibia; but of these the first two, counting from the head, the mandibular and the hyoid arches, have only a transitory existence and disappear very early.

In man the following changes take place: The portion of the dorsal longitudinal vessel, on each side, in the region between the third and fourth arches disappears. The portion above the third arch in which the current is directed towards the head forms part of the carotid system. Below the fourth arch two portions of the vessel may be recognized, viz., the aortic root and the mesial aorta, the latter being a common stem

formed by the union of the vessels of the opposite sides. The right aortic root disappears, the left forms a portion of the permanent aorta.

The fifth arch of the right side disappears entirely; that of the left side gives off from its ventral extremity a branch to each lung, and its continuation towards the root of the dorsal aorta becomes the ductus arteriosus, a vessel which is patent during foetal life, but becomes in the adult a solid cord. When the bulbus arteriosus is divided by a septum into two channels, that which is connected with the right ventricle becomes continuous with the fifth left arch and forms the base of the pulmonary artery, while the other, connected with the left ventricle, becomes the ascending aorta.

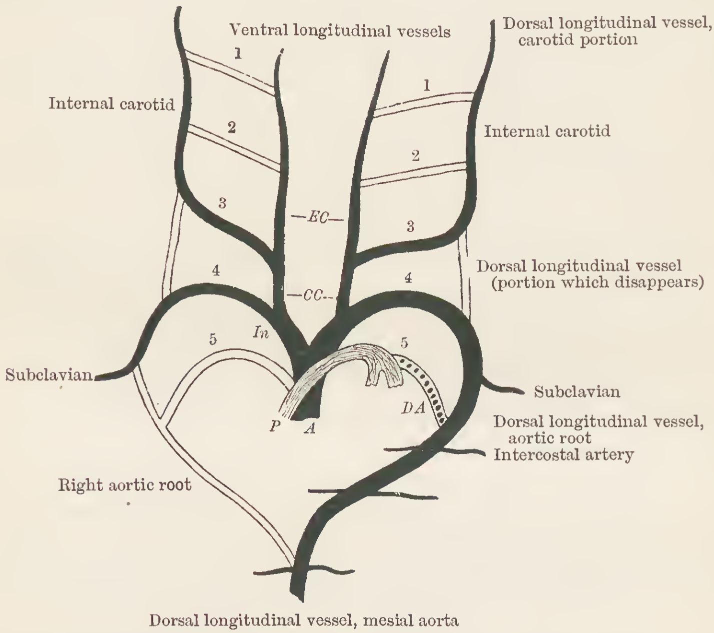

Fig. 367.—Diagram to Illustrate the Development of the Larger Arteries. 1 to 5, The primitive arterial arches. *EC*, External carotid; *CC*, common carotid; *In*, innominate; *P*, pulmonary; *A*, aorta; *DA*, ductus arteriosus. (After Rathke.) (J. Y. M.)

The fourth arch of the left side forms a portion of the arch of the aorta, and is continued by the left aortic root into the dorsal aorta. The left subclavian artery springs from the left aortic root near the place where the ductus arteriosus or fifth left arch enters. The ventral vessel of the right side, in the region below the fourth arch, becomes the innominate artery of the adult. The fourth arch of the right side persists as far as the place from which the right subclavian, corresponding in position to the left subclavian, springs, but its continuation beyond this as the right aortic root disappears. The fourth right arch is therefore represented in the adult by the basal portion of the right subclavian artery passing outwards from the innominate.

It is generally held, in accordance with Rathke, that in mammals the portions of the ventral vessels, which stretch from the extremities of the fourth arches to the third, form the common carotid arteries, that the further continuations of these vessels towards the ventral extremities of the higher early disappearing arches form the external carotid arteries, and that the third arches themselves and the highest portions of the dorsal vessels continued from them form the internal carotid arteries.

The fourth and fifth arterial arches, originally developed in the neck, descend with the heart into the thorax. The inferior laryngeal nerves turn round the lowest arch on each side, and on account of the descent of the heart and vessels take, in the adult, a recurrent course. Most of the varieties in the arrangement of the branches of the aorta are to be explained simply by variations in the growth of the aortic arch, branches being either approximated to or conjoined with one another or unduly separated from one another. One variety, however, that in which the innominate artery is absent, and the right subclavian comes off as the last branch of the arch, is specially interesting from a developmental point of view. In this case the fourth arch of the right side, which normally persists as the basal portion of the right subclavian, has disappeared; while, on the other hand, the right aortic root, a portion of the dorsal longitudinal vessel which, in normal circumstances entirely disappears, has persisted as the basal portion of the subclavian artery.

The Development of the Veins.

The heart, in the earliest stage, is joined at its venous extremity by the right and left *vitelline veins*, which bring the blood from the vascular area of the yelk sac; they open separately into the sinus venosus. A little later, on the establishment of the placental circulation, the right and left *umbilical veins* enter the sinus in close proximity to the vitelline veins. From an early period also there enter the sinus the right and left *ducts of Cuvier*, each of which, a short transverse vessel, is formed by the junction of the *primitive jugular vein* from the upper part of the trunk with the *cardinal vein* which returns the blood from the Wolffian body and the lower part of the trunk.

The portal system (Fig. 368). On the development of the liver the vitelline veins join with one another a little below the heart to form for a short distance a single vessel; between the single portion and the heart they break up into branches which, ramifying in the substance of the liver, become the *venae advehentes* and *revehentes* of the portal system. The veins from the intestinal canal join the single portion of the vitelline veins, which thus becomes the portal vein, and the original terminations of the veins in the sinus, continued from the venae revehentes, persist for a time as right and left hepatic veins.

In the substance of the umbilical cord the umbilical veins join with one another very early to form a single vessel, but within the trunk they

remain distinct from one another. They soon lose their direct connection with the sinus and join the right and left branches, respectively, of the portal vein, and their blood passes to the heart through the liver. A little later the right umbilical vein disappears, and from the left, at the place of its connection with the left portal vein, a new trunk, the *ductus venosus*, passing upwards to the right hepatic vein, is developed, and carries the most of the blood from the placenta to the heart. The left hepatic vein, in turn, loses its connection with the heart and falls into

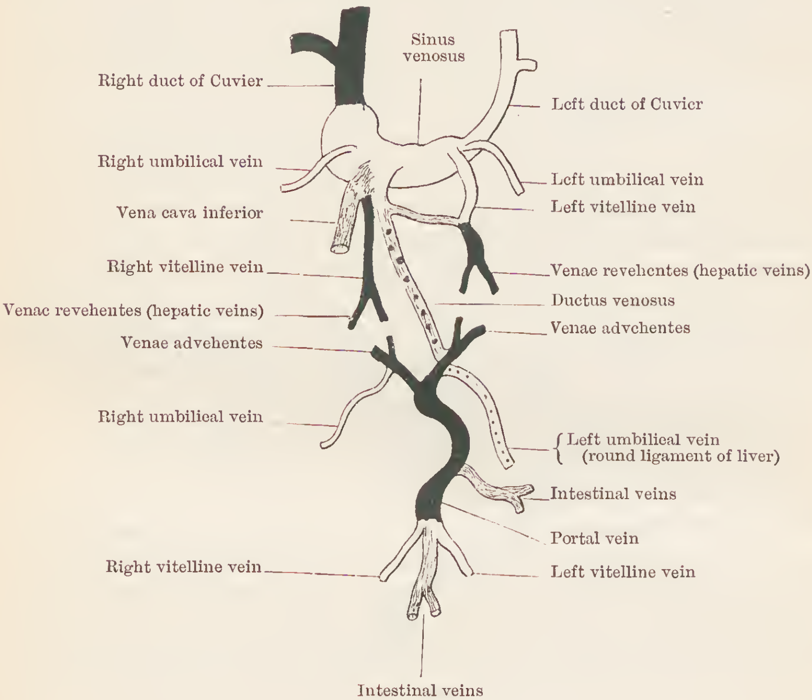

FIG. 368.—DIAGRAM TO ILLUSTRATE THE DEVELOPMENT OF THE PORTAL SYSTEM OF VEINS. The original veins which remain permanent are represented in black, those which disappear in outline. Veins later in appearing are shaded. Veins which remain as impervious cords are dotted. (After His.) (J. Y. M.)

the ductus venosus. With the development of the lower limbs the *inferior vena cava* appears, and joins the cardiac end of the ductus venosus. After birth, the left umbilical vein becomes a solid cord, the round ligament of the liver, passing to the left branch of the portal vein; from the posterior part of the left portal vein, the ductus venosus, which likewise becomes impervious, stretches to the inferior vena cava.

The systemic veins (Fig. 369). The *primitive jugular veins* which receive the blood from the cranial cavity and form the upper branches of the ducts of Cuvier, represent in the adult the external jugular veins; they are joined near their cardiac extremities by the subclavian and internal jugular

veins which are later of being formed. Between the primitive jugular veins of opposite sides, below the place of entry of the subclavian and internal jugular veins, there appears a transverse connecting branch. This transverse branch becomes the left innominate vein. The portion of the right primitive jugular on the distal side of the junction becomes the right innominate, the portion on the cardiac side and the right duct of Cuvier becomes the superior vena cava. Concomitantly with

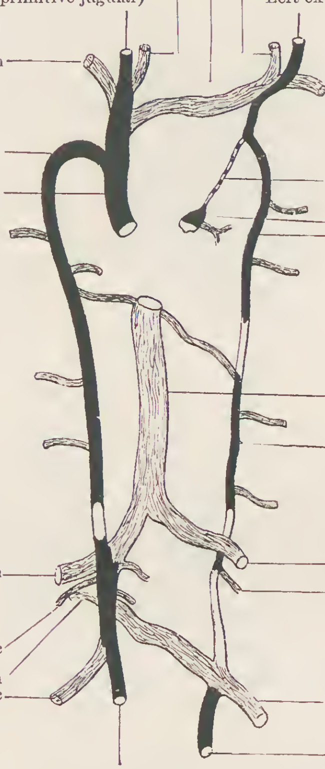

Fig. 369.—Diagram to Illustrate the Development of the Systemic Veins. The original veins which become permanent are represented in black. The portions which disappear are shown in outline. The veins which are developed later are shaded. The portions which remain as impervious cords are dotted. (After Hochstetter.) (J. Y. M.)

the development of the left innominate vein, which carries the blood of the left side to the right duct of Cuvier, the left duct of Cuvier undergoes atrophy; its basal portion however remains as the coronary sinus and the oblique vein of the heart, and the remainder of it is represented partly by the delicate fibrous cord which lies in the vestigial fold of Marshall, and, probably, in part by the uppermost portion of the left superior intercostal vein.

The *cardinal veins* receive at first the blood from the Wolffian bodies and the lower part of the trunk. In their distal portions they remain as the internal iliac veins, and receive as branches the external iliac veins from the limbs. In the abdominal portion of their course the cardinals at first receive the lumbar, spermatic, and renal veins, and, in the thoracic portion of their course, the intercostal veins. The inferior vena cava, developing from the heart, divides into two branches which unite with the right and left cardinal veins at the places of entry of the renal veins, and the new vessel to a large extent takes the place of the original trunks. The right branch of the two into which the inferior vena cava divides, with the portion of the right cardinal vein immediately below the place of junction, becomes the lower part of the main trunk of the permanent vena cava, namely, that portion which receives the right renal, right spermatic, and the lumbar veins; the portion of the right cardinal vein beyond the lower extremity of the inferior vena cava, between it and the lowest portion of all, which becomes the internal iliac vein, is represented in the adult by the right common iliac vein. Above the right renal vein a small portion of the right cardinal either disappears altogether, or remains as a slender connection between the renal vein or the vena cava, on the one hand, and the great azygos vein on the other. The thoracic portion of the right cardinal vein becomes the great azygos vein.

On the left side, a transverse branch passes from the upper extremity of the left internal iliac vein to the right cardinal, and becomes the left common iliac vein. Above this, the abdominal portion of the left cardinal disappears, save probably for a small part at the origin of the left spermatic vein. The left branch of the vena cava becomes the basal portion of the left renal vein. Above this the left cardinal is again interrupted. The lower part of the thoracic portion of the left cardinal vein becomes the left ayzgos vein and, by the development of a transverse branch, passes its blood into the right cardinal vein. Above the position of the transverse branch a portion of the left cardinal vein is usually atrophied. The highest portion remains as the greater part of the left superior intercostal vein.

The Circulation in the Embryo and Foetus.

The vitelline or omphalo-mesenteric circulation. The earliest vessels which are developed in connection with the embryo are those of the vascular area; they are formed in the mesoblast of the splanchnic wall of the yelk sac. From the vascular area the blood is carried to the venous end of the heart by two *vitelline veins*, and, after passing through the heart and the primitive arterial arches, reaches the dorsal aorta. From the abdominal portion of the dorsal aorta two *vitelline arteries*, at first very large in comparison with the other branches, carry the blood to the

vascular area. Within the area the arteries ramify and become connected peripherally with a circular vessel or sinus which, though venous in the bird, is arterial in the mammal. The capillaries of the vascular area absorb the nutritive material from the yelk sac.

The **placental circulation** (Fig. 370) becomes established in man about the fourth week. The blood returned from the placenta passes through the umbilical vein, from which it is carried through the *ductus venosus* into the hepatic veins, where it is mixed with the blood from the liver.

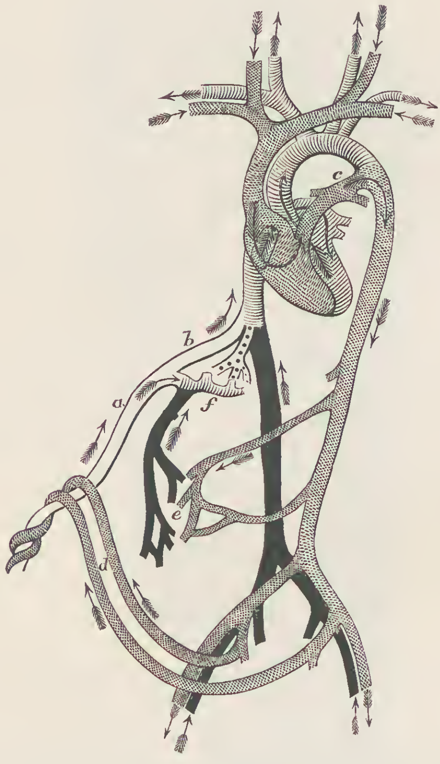

FIG. 370.—DIAGRAM OF THE FOETAL CIRCULATION. *a*, *b*, Umbilical vein: *c*, ductus arteriosus; *d*, hypogastric arteries; *e*, omphalo-mesenteric vessels; *f*, ductus venosus.

From the hepatic veins it enters the termination of the inferior vena cava, becoming mixed there with the blood from the lower limbs. Entering the heart by the orifice of the inferior cava, it is directed by the *Eustachian valve* through the *foramen ovale* into the left auricle. From the left auricle, where it becomes mixed with a small quantity of blood returning from the lungs, it falls into the left ventricle. From the left ventricle it enters the commencement of the aorta, and is carried thence, owing to the position and direction of the carotid and subclavian branches, almost entirely to the head and neck and upper limbs, from

which it returns to the right auricle of the heart by the superior vena cava. The blood from the superior vena cava passes through the right auricle into the right ventricle, and from thence is carried by the pulmonary arteries in small quantity to the unexpanded lungs, but in much greater quantity through the *ductus arteriosus*, the still patent fifth left arterial arch, to the dorsal aorta. A part of the blood within the dorsal aorta supplies the lower part of the trunk and the lower limbs, returning by the cardinal veins and the inferior cava; but the larger part, entering the internal iliac arteries, is carried by the right and left *hypogastric arteries*, to the placenta.

When the lungs become expanded, after the first few respirations, the pulmonary arteries rapidly dilate and draw off a large portion of the blood which, returning by the pulmonary veins to the left auricle, tends to close the valve of the foramen ovale. Subsequently the valve becomes completely closed. Instances of incomplete closure are, however, not uncommon, but the resulting passage between the auricles is usually small; when a considerable opening remains, the venous blood mixing with the arterial blood produces a cyanotic condition. The ductus arteriosus and the hypogastric arteries rapidly shrink and become, in two or three days, obliterated, and the ductus venosus and umbilical vein, a few days later, likewise become impervious. During foetal life there is not the same disproportion in thickness between the walls of the right and left ventricles, as is the case in the adult, owing, doubtless, to the fact that the resistance which each chamber has to overcome is, while the ductus arteriosus is still patent, about the same.

THE LYMPHATICS.

The *lymphatic vessels* or absorbents take up the lymph from the tissues; those of the intestine also take up the chyle and receive the special name of *lacteals.* The majority open into lymphatic glands; from the glands others pass onwards, and ultimately the contents of all are discharged into the venous system by the *thoracic duct* and the *right lymphatic duct.* The thoracic duct opens into the commencement of the left innominate vein; it carries the chyle, and the lymph from both lower limbs, the whole of the abdomen with the exception of a small portion of the upper surface of the liver, the whole of the left side and a portion of the right side of the thorax, the left upper limb, and the left side of the head and neck. The right lymphatic duct opens into the commencement of the right innominate vein; it carries the lymph from a small portion of the upper surface of the liver, the greater part of the right side of the thorax, the right upper limb, and the right side of the head and neck.

Fig. 371.—The Superficial Veins of the Thigh. (L. Testut.)

To face p. 496.

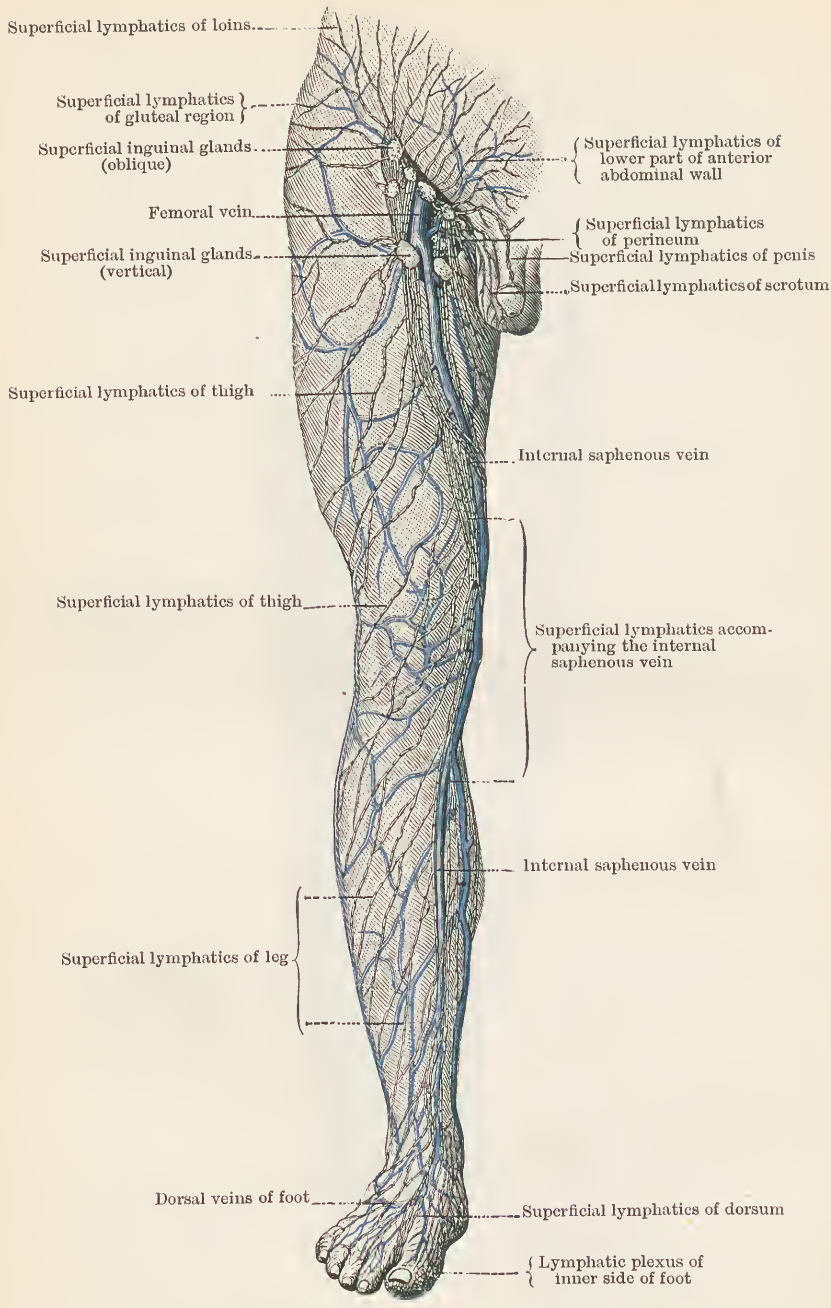

FIG. 372.—SUPERFICIAL LYMPHATICS OF THE LOWER LIMBS. (L. Testut.)

To face p. 497.

The **thoracic duct** (Fig. 359), about eighteen inches in length, commences in the upper part of the abdominal cavity, and ascends through the thorax to the neck, where it terminates by falling into the distal extremity of the left innominate vein. Its lower extremity is somewhat dilated and forms a thin walled sac, the *receptaculum chyli*, about an inch and a half in length, and a quarter of an inch in breadth, which lies upon the body of the second lumbar vertebra under cover of the right crus of the diaphragm, and to the right of and behind the aorta. As it ascends, the duct at first diminishes in breadth, but in the upper part of the thorax and in the neck its diameter gradually increases. A couple of valves prevent regurgitation at the venous orifice, and a large number are found in the course of the vessel. In the thorax the duct is placed, at first, to the right side of the aorta, between it and the great azygos vein, and rests upon the vertebral column and the right intercostal arteries. About the level of the fourth dorsal vertebra it crosses behind the arch of the aorta; thereafter it ascends upon the left side of the column behind the left subclavian artery, and on the left edge of the oesophagus. In the neck it runs upwards for a short distance behind and between the left carotid and subclavian arteries and then with a crook-shaped bend passes forwards, outwards, downwards, and eventually a little inwards, in front of the vertebral vein and the left subclavian artery, and terminates in the angle of union of the subclavian and internal jugular veins of the left side. The thoracic duct is subject to numerous variations. It may begin higher or lower than usual; the place at which it crosses behind the aorta is not constant; it is sometimes double in a part of its course, or even throughout; it may terminate partly, or entirely, in the veins of the right side of the neck; it sometimes passes behind the vertebral vein; finally, instead of falling into the extremity of the innominate vein, it may end wholly or partly in one of the neighbouring large veins at the root of the neck or the upper part of the thorax.

The receptaculum chyli receives the right and left lumbar trunks, and the mesenteric trunk; with the mesenteric trunk those of the coeliac glands are commonly associated. To the thoracic duct pass the efferent vessels from the whole of the left side of the thorax and a few of those from the lower part of the right side of that cavity; in the neck it is joined by the vessels from the left side of the head and neck and the left upper limb.

The **right lymphatic duct** (Fig. 374), about half an inch in length, is formed by the union of trunks bringing the lymph from the right side of the head and neck with those coming up from the right axillary glands, and terminates in the angle of junction of the right internal jugular and right subclavian veins. In addition, it receives the lymphatic vessels from the greater part of the right wall of the thorax, and those of the right lung and the right side of the heart.

LYMPHATICS OF THE LOWER LIMB.

Glands. One or two small glands are sometimes found by the side of the anterior tibial artery in front of the interosseous membrane of the leg.

The **popliteal glands**, four or five in number, are usually small, and lie among the fat of the popliteal space, by the side of the artery. They receive the deep vessels of the leg and, in addition, the few superficial vessels which pass deeply with the external saphenous vein.

The **superficial inguinal glands** (Fig. 372) form two groups; one, superior in position, forms an obliquely placed chain, parallel to Poupart's ligament; the other, inferior in position, is arranged in a vertical chain placed by the sides of the upper extremity of the internal saphenous vein. The individual glands are usually of considerable size. *The inferior group*, formed of four or five glands, receives all the superficial vessels of the lower limb with the exception of those of the gluteal region and the few which pass with the external saphenous vein into the popliteal space. *The superior group* is made up of a variable number of glands, usually eight or nine, which receive from above the superficial vessels of the lower part of the abdomen and back, and from below, internally, those from the penis, scrotum and perineum, and externally those from the gluteal region. The *efferent vessels* of the superficial inguinal glands pass through the saphenous opening, or pierce the fascia lata, and terminate, partly, in the deep inguinal and, partly, in the external iliac glands.

The **deep inguinal glands**, three or four in number, lie by the side of the upper extremity of the femoral vein. They receive the great majority of the deep vessels of the lower limb and many of the efferent vessels from the superficial glands. Their own efferent vessels pass to the external iliac glands.

Vessels. The **superficial lymphatics** (Fig. 372). A few from the back of the leg, ascending with the external saphenous vein, pass into the popliteal space and join the popliteal glands; by far the greater number are directed towards the internal saphenous vein, and ascend by its side to the inferior superficial inguinal glands. The superficial vessels of the gluteal region enter the outer part of the superior inguinal chain. The **deep lymphatics** accompany the arteries. Those by the side of the anterior tibial artery occasionally enter one or two glands which are sometimes found in front of the interosseous membrane. All those of the foot and leg pass to the popliteal glands, from which the efferent ducts ascend by the side of the femoral artery to the deep inguinal glands; the great majority of those from the thigh enter the deep inguinal glands, but one or two small vessels accompany the obturator artery and end in the internal iliac glands. The deep lymphatics of the gluteal region pass with the gluteal and sciatic arteries to the internal iliac glands, one or more small extrapelvic glands being sometimes found in their course.

LYMPHATICS OF THE ABDOMEN AND PELVIS.

Glands. The **external iliac glands**, three to five in number, surround the external iliac artery; they are of variable size, the lower ones being generally larger than the upper. They receive the efferent vessels of the deep inguinal glands and some of those of the superficial inguinal glands, and also the deep lymphatic vessels which, coming from the lower part of the abdominal wall, accompany the deep circumflex iliac and epigastric arteries. They discharge into the lumbar glands.

The **internal iliac glands**, usually twelve or thirteen, but variable in number, lie by the side of the internal iliac artery and its chief branches. They receive the deep lymphatic vessels of the gluteal region and the perineum, and a few which accompany the obturator artery from the adductor region of the thigh. They also receive the greater number of the lymphatic vessels from the bladder and prostate, those from the vesiculae seminales, and those from the vagina and the lower part of the uterus. Their efferent vessels pass to the lumbar glands.

The **sacral glands** are four or five in number. They lie in front of the sacrum along the line of attachment of the mesorectum. They are connected anteriorly with five or six *rectal glands* which lie between the folds of the mesorectum. The sacral glands receive the lymphatics of the sacral part of the pelvic wall, those of the rectum, and a few of the posterior vessels of the bladder and prostate. Their efferent vessels join the lumbar glands.

The **lumbar glands** are divided into three groups, two of them lateral, the third mesial in position. The *mesial glands*, six or seven in number, are of considerable size, and surround the aorta, extending upwards as far as the place of origin of the superior mesenteric artery. They receive the efferent vessels of the external iliac, internal iliac, and sacral glands, and some of those of the lateral lumbar glands. They receive, in addition, in the male, the lymphatics from the testicle, and, in the female, those from the upper part of the uterus and the ovary, and to them are also directed the vessels from the kidneys and suprarenal capsules, and from the vertebral portions of the diaphragm. They discharge themselves by right and left vessels into the receptaculum chyli. Into the left vessel the lymphatics from the sigmoid flexure and the lower part of the descending colon usually open. The *lateral groups* are made up of numerous small glands which lie behind the psoas muscles, between the successive transverse processes. They receive the deep lymphatic vessels of the posterior abdominal wall, and their efferent vessels pass partly to the mesial glands and partly to the receptaculum chyli.

The mesenteric glands. Several glands of considerable size surround the base of the superior mesenteric artery, and are connected distally with a very large number of small glands which lie between the layers of the mesentery. The small glands are arranged in an irregular

manner, and are scattered through the mesentery, most numerously, however, in the upper half, from the base to within two inches of the margin of the bowel; a special group near the termination of the artery receives the name of *ileo-colic.* The mesenteric glands receive the *lacteals* from the lower part of the duodenum, the jejunum, ileum, and a part of the ascending colon, and discharge themselves into the receptaculum chyli by a trunk which receives the efferent vessels of the mesocolic and coeliac glands. The **mesocolic glands**, twenty to thirty in number, and of small size, lie between the layers of the mesocolon, and receive the vessels from the transverse colon and the upper portions of the ascending and descending colon. Their efferent vessels pass to the duct of the mesenteric glands.

The **coeliac glands**, sixteen to twenty in number, lie in front of the aorta and surround the coeliac axis. They receive the lymphatic vessels of the greater part of the liver, the stomach, the upper part of the duodenum, the spleen, and the pancreas. Their efferent vessels, joining that of the mesenteric glands, enter the receptaculum chyli. Many of the lymphatics of the liver on their way to the coeliac glands pass through a number of small glands, the *hepatic glands*, which lie in front of the portal vein, between the layers of the small omentum. The vessels from the stomach are connected with small *superior* and *inferior gastric glands* which form chains upon the smaller and greater curvatures respectively. A few small *splenic glands* are found at the hilum of the spleen.

Vessels. Parietal lymphatics. The *superficial vessels of the perineum*, along with those of the *penis*, pass to the inner end of the superior superficial inguinal chain. The *deep vessels of the perineum* pass with the pudic arteries, and those of the *penis*, partly, with the pudic arteries and, partly, with the dorsal vein, to the internal iliac glands. The *superficial vessels of the abdominal wall* pass downwards to the superior superficial inguinal glands, and upwards to the axillary glands. The *deep vessels of the pelvic wall* pass to the internal iliac and sacral glands; those of the *abdominal wall* terminate in the external iliac, lateral lumbar, and mesial lumbar glands, and in the glands which lie by the sides of the internal mammary arteries.

Visceral lymphatics. The *vessels from the testicle* ascend in the cord to the lumbar glands, and those of the *ovary* and the *upper part of the uterus* have a similar termination. The vessels of the *lower part of the uterus and the vagina* end chiefly in the internal iliac glands, but a few accompanying the round ligament end in the superficial inguinal glands. Those of the *bladder, vesiculae seminales, and prostate gland* pass, in great part, to the internal iliac glands, but a few from the back of the bladder, in the male, join the rectal lymphatics, and with them reach the sacral glands. The lymphatics from the *kidneys and suprarenal capsules* pass to the lumbar glands.

Lymphatics of the intestine. The vessels from the rectum pass to the rectal glands, and thence to the sacral glands; those from the sigmoid flexure and the lower half of the descending colon join the duct of the left lumbar glands; those from the upper portion of the descending, the

whole of the transverse, and the upper portion of the ascending colon join the mesocolic glands; from the lower part of the ascending colon and from the whole small intestine, with the exception of the upper part of the duodenum, the vessels pass to the mesenteric glands. The lymphatics of the stomach and the upper part of the duodenum pass with the coronary and right gastro-epiploic arteries to the coeliac glands, and with the left gastro-epiploic to the splenic lymphatic vessels; they are connected with the superior and inferior gastric glands.

The lymphatics from *the spleen* are connected with the splenic glands, and are continued onwards to the coeliac glands, receiving as they go a few of the vessels from the stomach and those of *the pancreas.*

The *deep lymphatics of the liver* pass, partly, with the portal vein to the hepatic glands, and thence to the coeliac glands, and, partly, with the hepatic veins through the diaphragm, to terminate in a few glands which lie beside the thoracic portion of the inferior vena cava; the efferent ducts of these glands pass backwards to the lower end of the thoracic duct. The *superficial lymphatics of the liver* pass in several directions—(*a*) those from the *mesial portions of the upper surface* ascend between the layers of the falciform ligament, pierce the diaphragm behind the ensiform process, and join the anterior mediastinal glands, the efferent ducts from which pass partly to the right lymphatic duct and partly to the thoracic duct; (*b*) those from the *lateral portions of the upper surface* descend to the coeliac glands; (*c*) those from the *posterior border* pierce the diaphragm, and reach the glands in contact with the thoracic portion of the inferior vena cava; (*d*) those from the *under surface* join the deep lymphatics which accompany the portal vein, and like them are connected with the hepatic glands before reaching the coeliac glands.

THE LYMPHATICS OF THE THORAX.

Glands. The **anterior intercostal** or **sternal glands**, seven or eight in number on each side, are placed at the sternal extremities of the intercostal spaces by the sides of the internal mammary arteries. They receive a few of the lymphatics from the inner side of the mammary gland, the deep vessels of the anterior part of the chest wall, and those which accompany the superior epigastric and musculo-phrenic arteries. They are connected with the anterior mediastinal glands, and their efferent vessels pass upwards, on the right side, to the right lymphatic duct, and, on the left, to the thoracic duct.

The **posterior intercostal glands** form a group on each side of the spine at the vertebral extremities of the intercostal spaces. The individual glands are of very small size, and there are usually two or three in each interspace. They receive the deep lymphatics of the posterior part of the thoracic wall, and the hinder part of the parietal pleura, and those of the deep muscles of the back, and of the spine. The efferent

vessels pass mainly to the thoracic duct, but those from the higher glands on the right side join the right lymphatic duct.

The **anterior mediastinal glands**, three or four in number, lie behind the lower part of the sternum. They receive the lymphatics from the mesial portion of the upper surface of the liver, and some of the vessels of the diaphragm and pericardium: they are connected with the anterior intercostal glands, and discharge themselves into the right lymphatic and thoracic ducts.

The **superior mediastinal glands** surround the basal portion of the aorta. They form a large ill-defined group which is continuous, below, with the posterior mediastinal glands, and, on each side, with the bronchial glands. They receive lymphatic vessels from the heart, pericardium, and thymus gland. Their efferent ducts pass upwards on the sides of the trachea to the right lymphatic and thoracic ducts.

The **bronchial glands** (Fig. 374), very numerous, and in the adult of a very dark colour, surround the main bronchi and their primary subdivisions in the roots of the lungs. They receive the lymphatics of the lungs and some of those of the pleural membranes, and their efferent ducts pass upwards with those of the superior mediastinal glands.

The **posterior mediastinal glands**, ten to twelve in number, form a chain by the sides of the descending aorta. They receive some lymphatic vessels from the diaphragm, those of the oesophagus, and those of the posterior portion of the pericardium. Their efferent vessels pass chiefly to the thoracic duct, but a few of the higher on each side join those from the bronchial glands. Some small glands lie in contact with the thoracic portion of the inferior vena cava. They receive the superficial lymphatics of the posterior border of the liver and some of the deep lymphatics of the liver. Their efferent ducts pass backwards on the diaphragm to the thoracic duct.

Vessels. The *superficial vessels of the thoracic wall* pass to the axillary glands. The greater number of those from the *mammary gland* reach the group of axillary glands which is placed along the lower border of the pectoralis major, but a few from the inner side are directed to the anterior intercostal glands. The *deep parietal vessels* pass to the anterior and posterior intercostal glands, as do also those of the parietal pleura. The *lymphatics of the diaphragm* pass to the anterior and posterior mediastinal and intercostal glands. The *vessels from the lungs* and from the *visceral layer of the pleura* are directed to the bronchial glands. The *oesophageal lymphatics* end in the posterior mediastinal glands. Those of the *pericardium* pass to the anterior, superior, and posterior mediastinal glands. The *cardiac lymphatics* form a plexus on the surface of the heart and terminate in two trunks, that of the right side passing in front of the aorta, that of the left keeping to the left of the pulmonary artery, and both terminating in the superior mediastinal glands.

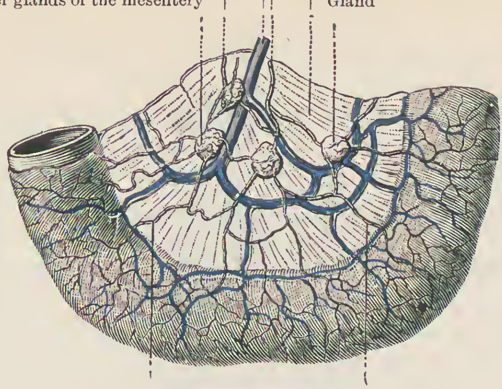

FIG. 373.—LYMPHATICS OF THE SMALL INTESTINE. (L. Testut.)

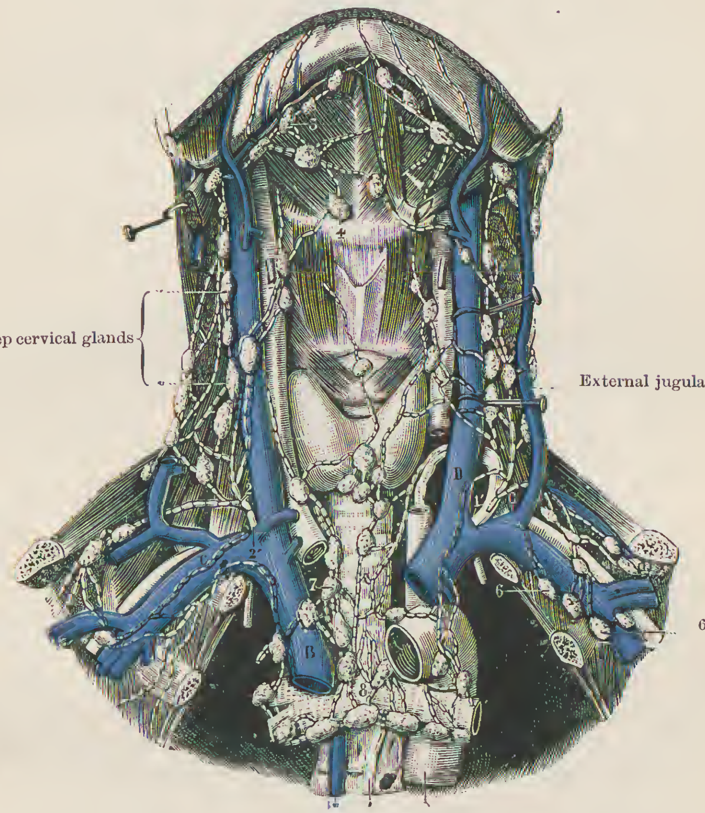

FIG. 374.—LYMPHATICS OF THE NECK AND THORAX. B, Superior vena cava; C, subclavian vein; D, internal jugular vein. 1′, Thoracic duct; 2, 2′, right lymphatic duct; 3, 4, submaxillary lymphatic glands; 6, axillary glands; 7, 8, bronchial glands. (L. Testut.)

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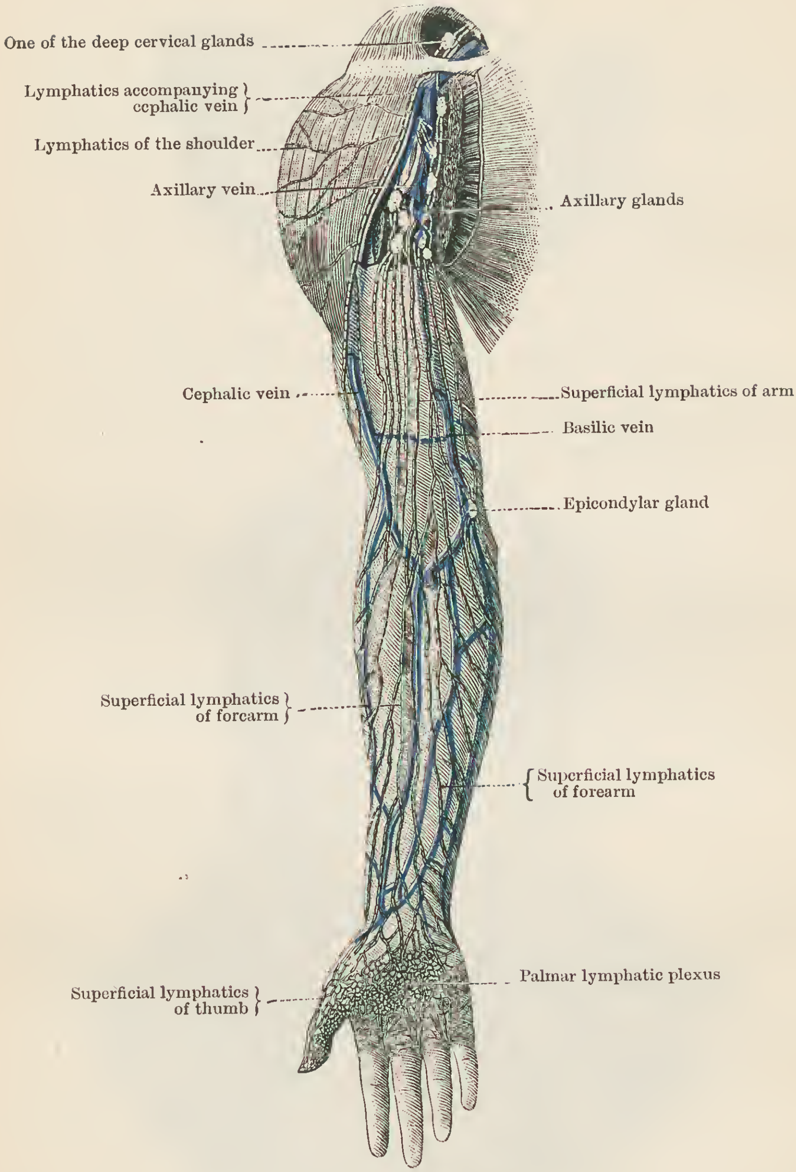

FIG. 375.—LYMPHATICS OF THE UPPER LIMB. (L. Testut.)

To face p. 503.

LYMPHATICS OF THE UPPER LIMB.

Glands. The **axillary glands** (Fig. 375), about twelve in number, are placed beneath the deep fascia of the axilla; they are arranged in four groups. The *main group*, formed of five or six glands, lies by the side of the axillary vessels; it receives the deep and most of the superficial lymphatic vessels of the limb. The *pectoral group* is placed at the lower border of the pectoralis major by the side of the long thoracic artery; it contains two or three glands, and receives the superficial vessels of the anterior region of the trunk from the level of the umbilicus to the clavicle, with the exception of a few from the inner side of the mammary gland. The *subscapular group* lies upon the subscapular artery at the posterior border of the axilla; it is formed of two or three glands, and receives the superficial vessels of the posterior surface of the trunk from the shoulder to the level of the iliac crest; many of these, crossing the middle line without communicating with the vessels which they pass, come from the opposite side of the body. The *infraclavicular group* is formed of one or two small glands which lie upon the costo-coracoid membrane; it receives a few of the outermost of the superficial lymphatics of the arm and some of those from the shoulder. The different groups of glands are freely connected with one another. Their efferent ducts, joining to form a single trunk, or remaining as three or four distinct vessels, pass upwards along the subclavian vein and fall, on the right side, into the right lymphatic duct, and on the left into the thoracic duct.

There are occasionally one or two small glands to be found in the course of the deep lymphatics by the side of the brachial artery, and in rare instances in the course of those which accompany one or other of the arteries of the forearm. In connection with the superficial lymphatics, one or two small *epicondylar glands* are very frequently met with a little above the internal epicondyle, close to the commencement of the basilic vein; and sometimes a small gland is found at the bend of the elbow.

Vessels (Fig. 375). The *superficial lymphatic vessels* form a very close meshwork on the palmar surfaces and on the sides of the fingers, and on the palm of the hand; from the greater part of this meshwork the collecting vessels pass to the dorsum of the hand, but at the wrist a number pass to the front of the forearm. In the forearm the ascending trunks tend to accompany the superficial veins; they are very numerous and communicate freely with one another. In the arm most of the vessels accompany the basilic vein, and a few of them usually terminate in the epicondylar glands. At the axilla the greater number pierce the fascia and terminate in the main group of the axillary glands, but a few from the outer side of the arm ascend with the cephalic vein, and end in the infraclavicular group of glands. In the course of the last mentioned vessels a small superficial gland is sometimes found (Sappey). The *deep lymphatic vessels*

accompany the arteries of the hand, forearm, and arm, and terminate in the main group of the axillary glands. Some of them, occasionally pass through a few small glands which lie by the side of the brachial artery.

LYMPHATICS OF THE HEAD AND NECK.

Glands (Fig. 376). In most cases one or two **occipital** glands of small size overlie the occipital origin of the trapezius muscle; when present they receive the vessels from the posterior region of the scalp, and discharge themselves into the superficial cervical glands.

The **mastoid** glands, one or two in number and of small size, lie behind the ear above the line of insertion of the sterno-mastoid muscle. They receive some of the vessels from the lateral and posterior region of the scalp and those from the back of the pinna. According to Sappey there are a number of mastoid glands on the deep surface of the sterno-mastoid close to the insertion, receiving there the efferent ducts of the more superficially placed glands, and some of the vessels from the scalp. The mastoid glands are generally regarded as sending their efferent ducts to the superficial cervical glands, and the glands of Sappey are probably connected with the deep cervical glands.

The **parotid lymphatic glands**, ten to twelve in number (Sappey), are placed under the fascia which covers the parotid gland, some of them being imbedded in the glandular tissue. They receive vessels from the parotid gland, and from the anterior and lateral regions of the scalp, the lateral parts of the face, and the front of the pinna of the ear. Their efferent ducts pass, partly, to the submaxillary and, partly, to the superficial cervical glands.

The **submaxillary lymphatic glands**, ten to twelve in number, occupy the digastric triangle; one or two of the most anterior of them receive the name of *suprahyoid glands.* The vessels which reach them come from the anterior part of the face, the floor of the mouth, the anterior part of the tongue, the submaxillary and sublingual salivary glands, and from the more anteriorly placed of the parotid lymphatic glands. Their efferent ducts pass partly to the superficial cervical glands and partly to the superior deep cervical glands.

The **superficial cervical glands** lie in the superficial fascia of the neck, the majority forming a chain at the posterior border of the sterno-mastoid muscle. They receive all the superficial vessels of the neck, and the efferent ducts of the occipital glands, some of those of the parotid and submaxillary groups, and probably some of those of the mastoid glands. They discharge themselves into the inferior deep cervical glands.

The **internal maxillary glands**, five or six in number, are placed in the zygomatic fossa. They receive vessels from the temporal and zygomatic regions, the orbit, the roof of the mouth, the soft palate, the nasal cavity, and the upper part of the pharynx, and their efferent ducts

pass to the superior deep cervical glands. A small *postpharyngeal gland* lies upon the vertebral column; it receives vessels from the pharynx and the prevertebral muscles.

The **superior deep cervical glands** form a chain which lies by the side of the internal jugular vein, in the region between the base of the skull and the thyroid cartilage. They receive the lymphatics of the cranial cavity, the efferent ducts of the internal maxillary glands, and some of those of the parotid and submaxillary groups, the vessels from the posterior part of the tongue, the lower part of the pharynx, the upper part of the larynx, the upper part of the thyroid body, and those from the deep muscles of the upper part of the neck. In connection with the lymphatics from the posterior part of the tongue one or two small *lingual glands* are found on the outer surface of the hyo-glossus muscle. The efferent ducts from the superior deep cervical glands are continued to the inferior deep cervical glands.

The **inferior deep cervical glands** are found by the side of the lower part of the internal jugular vein. They receive the efferent ducts of the superior deep cervical glands and those of the superficial cervical glands, and the vessels from the lower part of the larynx, the lower part of the thyroid body, the cervical portions of the trachea and oesophagus, and the deep muscles of the lower part of the neck. The vessels from the lower part of the larynx pass through one or two small *laryngeal glands* which lie by the side of the upper part of the trachea. The efferent ducts from the deep cervical glands unite to form the *jugular lymphatic trunk* which opens, on the right side, into the right lymphatic duct, on the left, into the thoracic duct, or, occasionally, on one or both sides, into one of the great veins at the root of the neck.

Vessels. The **superficial lymphatics** (Fig. 376). The *lymphatics of the scalp* pass to the occipital or, when these are absent, to the superficial cervical glands, and to the mastoid and parotid glands; from the *eyelids* and the *upper lateral region of the face* the lymphatics pass to the parotid glands; from the *nose*, *lips*, and *lower lateral region of the face* they pass to the submaxillary glands. From the *external ear* the lymphatics are directed to the parotid and mastoid glands. The *superficial lymphatics of the neck* are received by the superficial cervical glands.

The **deep lymphatics.** The *lymphatics of the brain* form plexuses in the pia mater, and are afterwards collected into larger trunks which escape from the cranium by the sides of the carotid and vertebral arteries and the internal jugular veins, and terminate in the superior deep cervical glands. The *meningeal lymphatics* accompany the meningeal arteries to the internal maxillary and superior deep cervical glands. The *lymphatics of the spinal cord* pass outwards through the intervertebral foramina by the sides of the entering arteries, and terminate, according to the region, in the deep cervical, posterior intercostal, and lateral lumbar glands. The lymphatics from *the orbit* enter the internal maxillary glands, as do also

those of *the nasal cavities*, *the roof of the mouth*, and the *temporal* and *zygomatic fossae*.

The lymphatics of the *floor of the mouth* and the *anterior part of the tongue* pass to the submaxillary glands; those of the *posterior part of the tongue* pass through the lingual glands to the superior deep cervical glands. The lymphatics from *the pharynx* pass partly to the internal maxillary and partly to the superior deep cervical glands. The lymphatic vessels from the *parotid salivary gland* end in the internal maxillary and parotid groups of glands; those from the *submaxillary and sublingual salivary glands* enter the submaxillary lymphatic glands. The *lymphatics of the larynx* form two sets; those above the glottis pass upwards through the thyro-hyoid membrane to the superior deep cervical glands; those below the glottis, piercing the crico-thyroid membrane, end in the inferior deep cervical glands. The lymphatics of the *thyroid body* accompany the upper and lower thyroid arteries to the superior and inferior deep cervical glands. Those of the *cervical portions of the trachea and oesophagus* enter the inferior deep cervical glands.

THE NERVES.

I. CEREBRO-SPINAL NERVES.

From the central organ of the nervous system, the brain and spinal cord, there spring on each side forty-three nerve-trunks, the branches of which are distributed throughout the body. Thirty-one pairs, taking origin from the cord, are termed *spinal nerves*; twelve spring from the brain and are called *cranial nerves*; one of the cranial nerves, however, the eleventh, receives many of its fibres from the cervical region of the cord.

Physiologists have divided nerve fibres into two classes according as they conduct impulses to or from the central organ: those which carry impulses to the centre are *afferent* or centripetal fibres; those which conduct from the centre and towards the periphery are *efferent* or centrifugal fibres. The dorsal roots of the spinal nerves contain only afferent fibres; the ventral roots on the other hand are formed of efferent fibres; beyond the place of junction of the roots with one another the trunk of each spinal nerve contains both kinds of fibres, and is termed a *mixed trunk*. Certain of the cranial nerves contain only one kind of fibre, others are mixed nerves. As the nerve-trunks approach the areae of their peripheral distribution the different kinds of fibres of which they are composed separate from one another. Thus, mixed trunks break up ultimately into branches, each of which is either afferent or efferent, and has its own special distribution. It may further be remarked concerning cutaneous nerves, that allied nerves are supplied to contiguous areae. Thus, the posterior divisions of the spinal nerves supply one contiguous area of in-

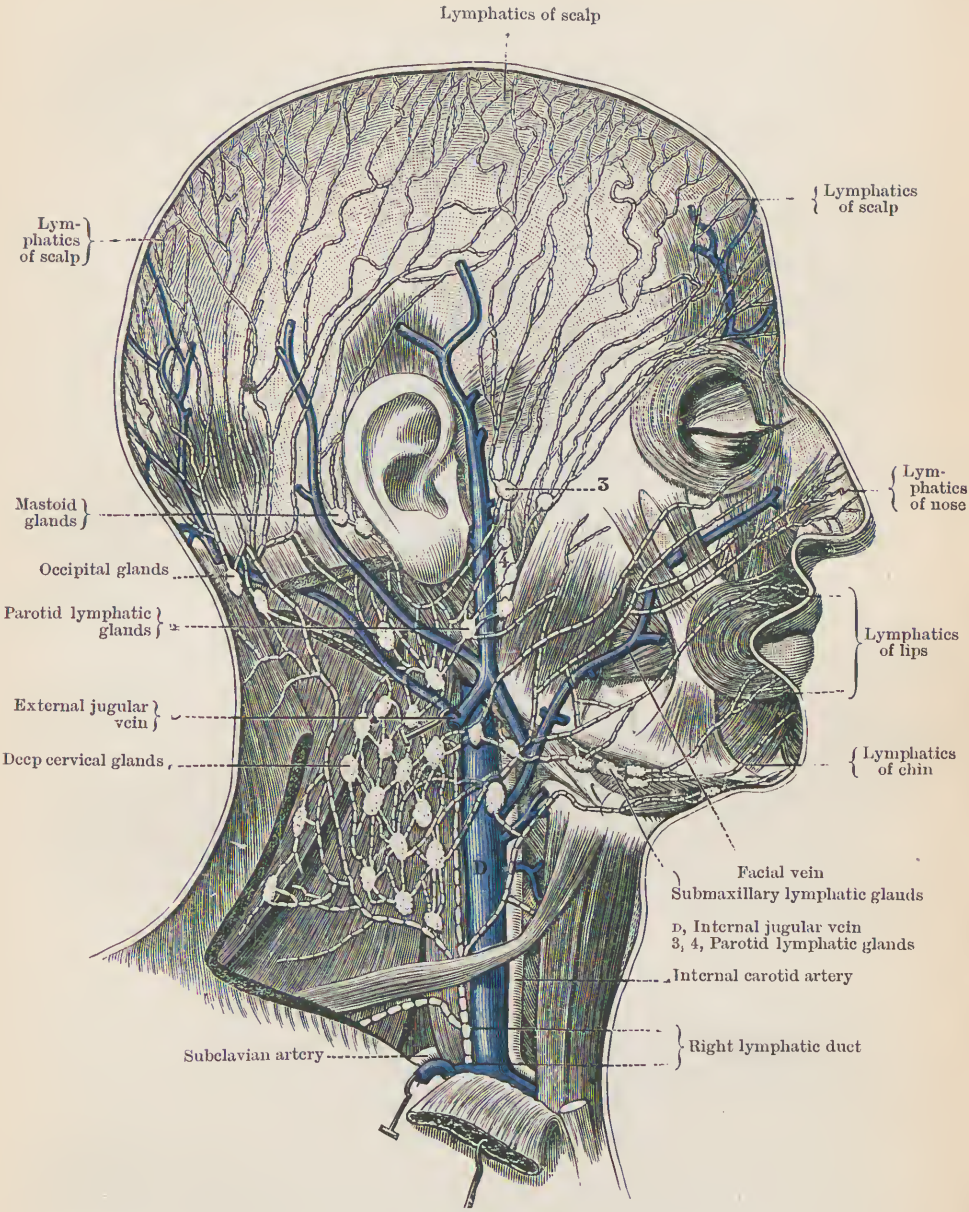

FIG. 376.—LYMPHATICS OF THE HEAD AND NECK. (L. Testut.)

To face p. 506.

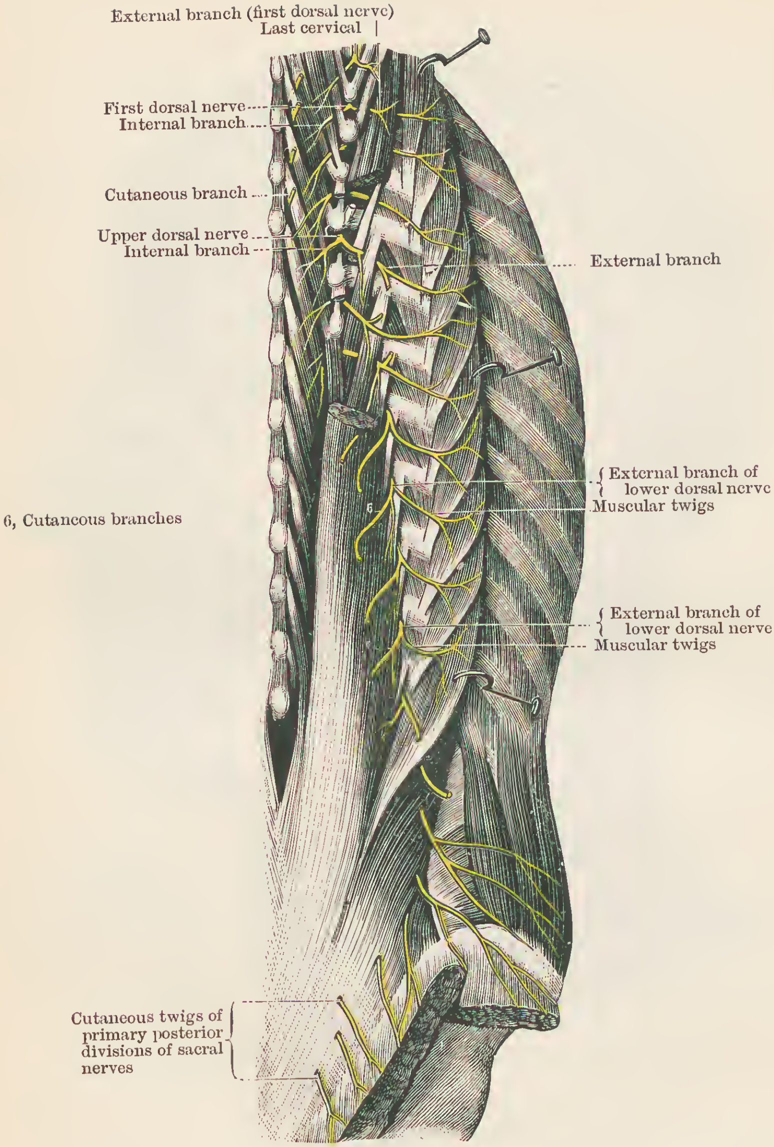

FIG. 377.—THE POSTERIOR PRIMARY DIVISIONS OF THE THORACIC AND LUMBAR NERVES. (L. Testut.)

To face p. 507.

tegument from the crown of the head to the gluteal region; the three branches of the fifth cranial, though reaching the face by different routes, together supply the whole face, and the head in front of the ear; and the cutaneous branches of the musculo-spiral in the upper limb, and those of the small sciatic, the great sciatic, and the anterior crural in the lower limb, all follow the same law.

SPINAL NERVES.

There are thirty-one pairs of spinal nerves, as follows: eight cervical, twelve thoracic, five lumbar, five sacral, and one coccygeal. The first nerve, the *suboccipital*, passes outwards between the occipital bone and the atlas; the next seven appear in order below the successive cervical vertebrae. The remaining nerves of the series are named from the vertebrae below which they escape. The coccygeal nerve issues from the lower extremity of the spinal canal, and passes outwards beneath the first piece of the coccyx.

Each nerve springs from the sides of the cord by two roots, an anterior and a posterior. The *posterior roots* are formed of afferent fibres; each of them presents a ganglion, involving most of its fibres, situated close to the place of junction with the anterior root. The *anterior roots* contain efferent fibres, and have no ganglia. With the exception of the case of the suboccipital nerve, in which the motor root is the larger, the posterior roots exceed the anterior in size, the discrepancy being most marked in the cervical region, and least apparent among the dorsal nerves. The roots, invested by the pia mater, traverse the subarachnoid and arachnoid spaces, and pass towards the intervertebral foramina, on a level with which they separately pierce the sac of the dura mater. In each foramen, surrounded by a common sheath, the anterior and posterior roots join with one another to form the nerve; at the outer extremity of the foramen the nerve breaks up into *anterior* and *posterior primary divisions*, each consisting of mixed fibres from the two roots. The ganglia are placed in the intervertebral foramina, and lie outside the common sac, but within the tubular prolongations of the dura mater. The arachnoid membrane is reflected upon the roots, but the investments from the dura mater and pia mater become continuous with the sheaths of the nerves. The last sacral and coccygeal nerves are formed, by the junction of the roots, within the common sac of the dura mater at some distance from their places of exit. In the case of the other sacral nerves, the primary divisions of which escape through the anterior and posterior sacral foramina, the junction of the roots, although taking place outside the sac of the dura mater, is effected within the spinal canal. The first and second nerves are formed opposite the posterior arches of the atlas and axis respectively.

Each posterior root springs from the postero-lateral groove of the cord by some six or eight fasciculi, which form a linear series. The ganglion is usually bilobate at its inner extremity, and the bundles of the root are

gathered into two before reaching it. Each anterior root takes origin by some four or five sets of bundles which do not form a linear series, but are scattered in an irregular manner over a certain breadth in front of the lateral column of the cord. The roots of the successive nerves arise from the cord at intervals. Those of the first nerves ascend slightly to the place of exit; those of the second and third pass outwards almost horizontally; the others, in order from above downwards, descend with increasing degrees of obliquity. In the case of each nerve there is considerable variation, but, as a general rule, among the upper dorsal nerves the roots take origin from the cord opposite the vertebra immediately above the one beneath which the nerve which they give rise to emerges, while, among the lower dorsal and upper lumbar nerves, the roots arise opposite the second vertebra above that beneath which the nerve which they form makes its exit from the spinal canal. The lower lumbar, the sacral, and the coccygeal nerve roots arise from the terminal portion of the cord opposite the first lumbar vertebra, and, descending in the subarachnoid space, form the *cauda equina*. The splitting of each nerve trunk into anterior and posterior divisions takes place immediately after its exit from the intervertebral foramen.

The *posterior primary divisions* of the nerves are, with the exception of those of the first and second nerves, smaller than their corresponding anterior divisions. Their distribution is limited to the muscles which occupy the furrows by the sides of the spines, and to the integument of the back. *The anterior divisions* supply the limbs and the anterior and lateral regions of the trunk. They communicate directly with the sympathetic chain. In the cervical, lumbar, and sacral regions they form plexuses.

Deep connections of the roots of the spinal nerves. The *posterior roots* are formed of afferent fibres, which are connected with the cells of the spinal ganglia. Passing inwards from the ganglia, the fibres of the root reach the spinal cord, within which each divides into an ascending and a descending branch; from the fibre before its division, and from each of its two branches, numerous slender collaterals are detached. The fibres terminate in the grey matter of the posterior horn, and probably also in that of the intermediate region of the cord, by breaking up into numerous delicate arborizations, which in their ramification come into close contact with the nerve cells or with their processes, but never communicate directly with them. The collaterals terminate, as do the main branches of the fibres, in ramifications, which surround nerve cells. Some of them pass into the anterior horn of the grey matter of the same and the opposite side of the cord, and surround the cells which give origin to the anterior or efferent roots.

The *anterior roots* are formed of fibres which are the continuations of the axis-cylinders of cells in the anterior, and probably also in the intermediate regions of the grey matter. These cells are surrounded by

the arborizations of the collaterals of posterior root fibres, and in addition by the lateral or terminal branches of fibres which descend from cells of the anterior cornua at a higher level, from the cerebellum, and from the cerebral cortex.

THE POSTERIOR PRIMARY DIVISIONS.

From their places of origin they are at once directed backwards, passing behind a line of muscles by which, in the neighbourhood of the openings of the intervertebral foramina, they are separated from the anterior divisions. This line is represented in the neck by the rectus capitis lateralis and the posterior intertransverse muscles, in the thoracic region by the levatores costarum and the external intercostals, in the loins by the external intertransverse and quadratus lumborum muscles. With the exception of the first cervical, the last two sacral, and the coccygeal, each member of the series divides into an *external* and an *internal branch.* These branches immediately on their origin diverge from one another, the line of separation being marked in the neck by the line of the origins of the complexus muscle, in the thoracic region by the intertransverse ligaments, and in the loins by the internal or median intertransverse muscles. Both external and internal branches give off muscular twigs. The special muscles in the different regions which are supplied by them are the short posterior cranio-vertebral muscles, the interspinales, the internal lumbar intertransverse muscles, the multifidus spinae, semispinalis, erector spinae, and splenius. The cutaneous supply is furnished by the internal branches in the cervical and upper dorsal regions, and by the external branches in the lower dorsal, lumbar, and upper sacral regions.

The Posterior Divisions of the Cervical Nerves.

The *posterior division of the first cervical or suboccipital nerve* does not divide into an internal and an external branch. It is a short trunk which passes backwards over the posterior arch of the atlas, beneath the vertebral artery, and breaks up into a number of twigs which supply the four short posterior cranio-vertebral muscles. It likewise gives a twig to the complexus, and occasionally furnishes a cutaneous branch which ramifies over the back of the occiput.

The *external branches* of the cervical nerves, from the second to the eighth, are small and entirely muscular in their distribution; they are directed outwards to the cervical portion of the erector spinae and to the splenius.

The *internal branches, from the second to the fifth,* pass inwards under cover of the complexus muscle. They give off muscular twigs to the multifidus spinae, semispinalis, complexus, and interspinales, and, in addition, furnish cutaneous branches, which pierce the trapezius close to the middle line.

The cutaneous branch of the second nerve is of large size, and is known as the *great occipital* (Fig. 379). It is directed upwards behind the obliquus capitis inferior muscle, and pierces the complexus below the outer margin of the occipital origin of the trapezius. Its branches ramifying with those of the occipital artery supply the integument covering the upper part of the occipital and the posterior part of the parietal bone, and form connections externally with those of the small occipital nerve from the cervical plexus.

The cutaneous branch of the third nerve, under the name of *third or smallest occipital nerve*, is directed upwards towards the occiput by the inner side of the great occipital nerve. On the deep surface of the complexus, small connecting twigs pass between the suboccipital nerve and the internal divisions of the second and third cervical nerves. The cutaneous branches of the fourth and fifth nerves are distributed to the integument of the back of the neck. The *internal branches of the sixth, seventh, and eighth nerves* are very small; they are distributed to the multifidus, semispinalis, complexus, and interspinales, and furnish, as a rule, no cutaneous twigs.

The Posterior Divisions of the Thoracic Nerves.

The *internal branches* (Fig. 377) supply the deeper muscles; the upper six or seven, in addition, furnish cutaneous offsets, which pierce the trapezius close to the spines and ramify outwards over the back, that of the second, the largest of the series, reaching almost to the back of the shoulder.

The *external branches* supply the erector spinae muscle. From the lower five or six, cutaneous twigs are detached; these pierce the latissimus dorsi at a little distance from the middle line, and are chiefly directed outwards and downwards.

The Posterior Divisions of the Lumbar Nerves.

The *internal branches* are small, and supply the multifidus, the interspinales, and the internal intertransverse muscles.

The *external branches of the first three* supply the erector spinae, and furnish cutaneous offsets which pierce the aponeurosis of the latissimus dorsi at the outer border of the erector spinae, immediately above the iliac crest, and are continued downwards in the subcutaneous tissue of the gluteal region, the lowest reaching as far as the level of the great trochanter.

The *external branch of the fourth* is small and does not, as a rule, reach the surface, but terminates in the erector spinae.

The *external branch of the fifth* descends to join that of the first sacral.

The Posterior Divisions of the Sacral Nerves and the Coccygeal Nerve.

The first four escape by the posterior sacral foramina; the fifth and the coccygeal make their exit from the lower extremity of the spinal canal.

The *internal divisions of the first three* are small and end in the multifidus spinae.

The *external branches of the first three* form with one another, and with that of the last lumbar nerve, a series of loops on the back of the sacrum; from the loops branches proceed to a second series of loops in the substance or on the posterior surface of the great sacro-sciatic ligament; from the secondary loops two or three branches pass to the surface, perforating the gluteus maximus and supplying the skin over its lower and inner part.

The *fourth and fifth sacral and the coccygeal nerves.* The posterior divisions of these nerves are of small size, and do not divide into external and internal branches; they form with one another, and with a small branch from the third sacral, a series of delicate loops, from which slender twigs pass to the skin in the neighbourhood of the coccyx.

THE ANTERIOR PRIMARY DIVISIONS.

The Cervical Plexus.

The cervical plexus is formed from the anterior primary divisions of the first four cervical nerves. Those of the third and fourth are the largest of the series, that of the first is a comparatively slender trunk. The first nerve of the plexus passes forwards between the rectus capitis lateralis muscle and the rectus capitis anticus minor, and descends in front of the base of the transverse process of the atlas to join the ascending branch of the second; the others emerge between the anterior and posterior intertransverse muscles, and lie in a plane immediately in front of the origins of the scalenus medius. The second and third nerves divide into ascending and descending branches which, uniting with one another, with the first nerve above, and with the fourth nerve below, form a series of three loops. The branches of the plexus are divided into superficial and deep groups.

SUPERFICIAL BRANCHES.

The superficial branches, passing backwards and outwards from their origins, emerge from under cover of the sterno-mastoid opposite the middle third of its posterior border. They are arranged in ascending and descending groups: in the former are the small occipital, the great auricular, and the superficial cervical; in the latter are the supra-acromial, the supraclavicular, and the suprasternal.

The **small occipital nerve** (Fig. 379) is derived from the loop formed by the second and third nerves. It ascends along the posterior border of the sterno-mastoid, and divides into *mastoid* and *occipital branches*, which supply the integument covering the mastoid, the outer part of the occipital, and the lower part of the parietal region of the skull; a slender *auricular branch* is directed forwards to the skin of the upper part of the inner surface of the pinna. The small occipital nerve is of variable size, and occasionally is

double; its branches form connections with those of the great occipital, great auricular, and posterior auricular nerves.

The **great auricular nerve** springs from the second and third nerves, and emerges from the cover of the sterno-mastoid immediately below the small occipital nerve. Crossing the muscle obliquely it passes upwards and a little forwards, under cover of the platysma, towards the region of the ear, beneath which it divides into *mastoid*, *facial*, and *auricular branches.*

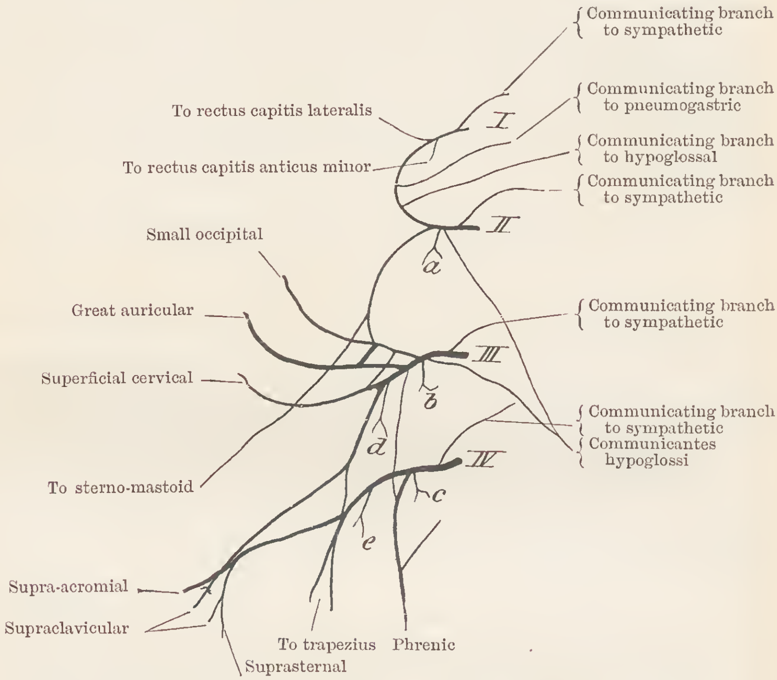

FIG. 378.—DIAGRAM OF THE CERVICAL PLEXUS. *a*, *b*, *c*, To rectus capitis anticus major, longus colli, and intertransversales; *d*, *e*, to scalenus medius, and levator anguli scapulae. (J. Y. M.)

These supply the integument covering the mastoid process, the parotid region of the face, the inner surface of the pinna, and partly also, by means of slender perforating twigs, the outer surface of the pinna. The branches form connections with those of the small occipital and facial nerves.

The **superficial cervical nerve**, from the second and third nerves, emerges below the great auricular, and, passing forwards under cover of the platysma, breaks up into numerous branches, which supply the skin of the front of the whole length of the neck. Two or three of the upper branches are connected with those of the inframaxillary branch of the facial nerve, forming loops of considerable size.

The **descending branches**, variable in number, spring from the third and fourth nerves, and descend under cover of the platysma; near the clavicle they break up into *suprasternal*, *supraclavicular*, and *supra-acromial* terminal twigs. They supply the lower and lateral regions of the neck,

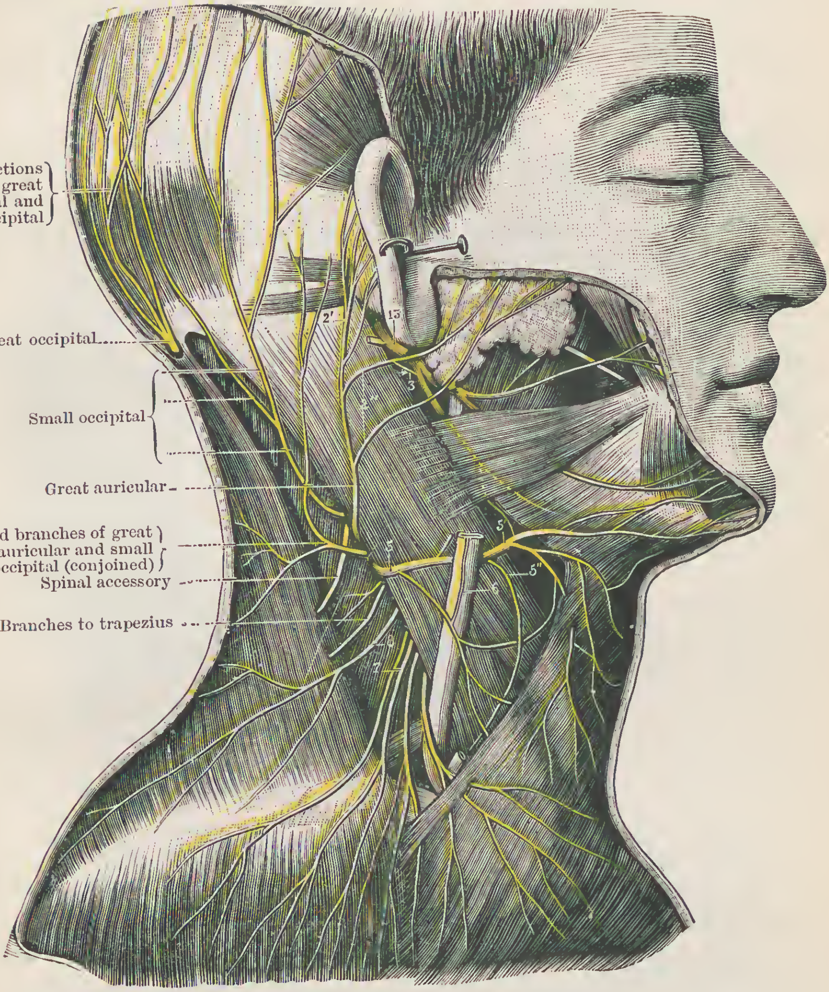

FIG. 379.—THE SUPERFICIAL NERVES OF THE NECK. 2′, 2″, Branches of great auricular; 3, connecting twig with inframaxillary of facial; 5, 5′, 5″, 6, superficial cervical; 7. 8, descending superficial branches of cervical plexus; 13, facial. (L. Testut.)

To face p. 512.

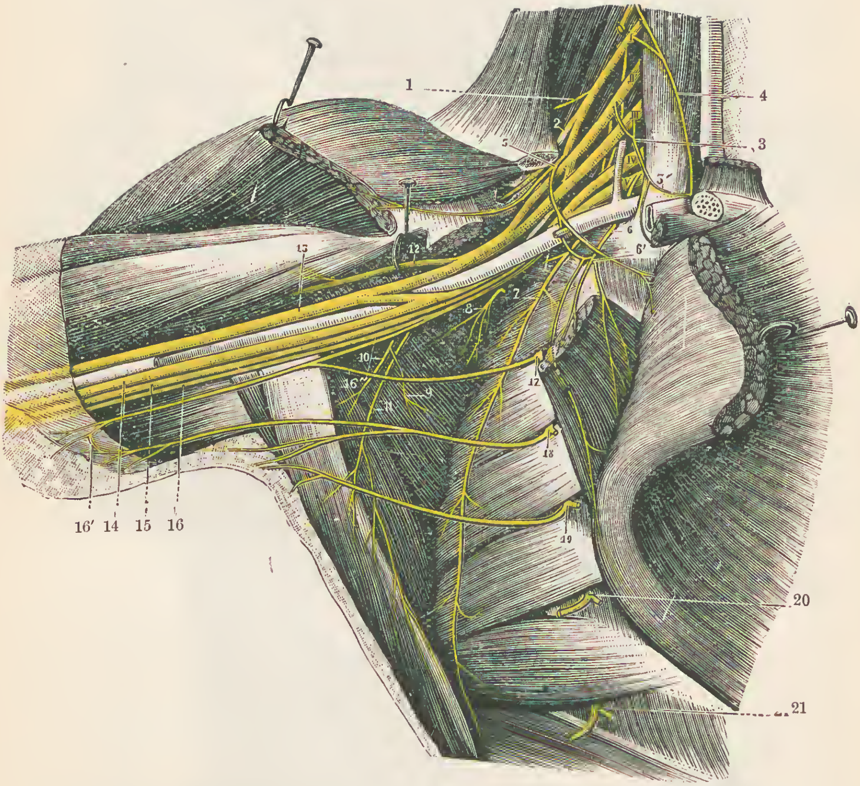

FIG. 380.—NERVES OF THE AXILLA. 1, Nerve to the rhomboids; 2, suprascapular; 3, nerve to subclavius; 3′, connections with phrenic nerve; 4, phrenic; 5, external anterior thoracic; 6, internal anterior thoracic; 6′, connection between external and internal anterior thoracic; 7, posterior thoracic; 8, short subscapular; 9, 10, lowest subscapular; 11, long subscapular; 12, external cutaneous; 13, median; 14, ulnar; 15, internal cutaneous; 16, lesser internal cutaneous; 16′, 16″, connections between lesser internal cutaneous and intercostal branches; 17, intercosto-humeral; 18, 19, 20, 21, lateral branches of 3rd, 4th, 5th, and 6th intercostal nerves. I. to V., The nerve trunks which form the brachial plexus; the primary cords of the plexus have been dissected up in order to show the formation of the outer and inner cords; the nerve to the subclavius is represented as receiving an unusual root from the seventh cervical nerve. (L. Testut.)

To face p. 513.

and their terminal branches reach the pectoral region and the shoulder. The suprasternal branches are slender, and pass forwards across the sterno-mastoid to the integument in front of the manubrium. The supra-clavicular branches cross the clavicle and supply the skin covering the upper part of the pectoralis major. The supra-acromial branches ramify over the upper part of the deltoid.

DEEP BRANCHES.

Connecting branches pass from each of the main trunks *to the first ganglion of the sympathetic*, and from the first loop to the *pneumogastric* and *hypoglossal nerves.*

The **muscular branches** are divided, according to the direction in which they pass, into an outer and an inner group.

Those of the **outer group** supply the sterno-mastoid, trapezius, scalenus medius, and levator anguli scapulae. The *nerve to the sterno-mastoid* springs from the second nerve; entering the deep surface of the muscle it forms connections with the spinal accessory nerve. The *nerves to the trapezius* are generally two in number, and are of considerable size; they spring from the third and fourth nerves, in association with the descending superficial nerves; under cover of the trapezius they are freely connected with the spinal accessory nerve. The *branches to the scalenus medius* and *levator anguli scapulae* are of small size, and spring from the third and fourth nerves.

The branches belonging to the **inner group** supply the rectus capitis anticus minor, the rectus capitis lateralis, the upper cervical intertransverse and prevertebral muscles, and the diaphragm, and assist in the supply of the infrahyoid muscles; the majority are slender twigs which pass at once into the muscles from the neighbouring nerve trunks. The *branches to the infrahyoid* muscles (*rami communicantes hypoglossi*), two in number, spring separately from the second and third nerves. They usually join with one another to form a single trunk, which passes inwards and downwards, crossing the carotid sheath superficially, and unites with the descending branch of the hypoglossal nerve to form a loop, the *ansa hypoglossi*, from which twigs proceed to the sterno-hyoid and sterno-thyroid muscles, and the posterior belly of the omo-hyoid.

The **phrenic nerve**, along with its fellow of the opposite side, supplies the diaphragm. It springs mainly from the fourth cervical nerve, but receives usually a slender twig from the third nerve, and, as a rule, is connected with the fifth nerve, the first of the brachial plexus. It descends in the neck, crossing anteriorly, from above downwards, the scalenus anticus muscle. In the lower part of the neck and upper part of the thorax, the relations of the nerves of the opposite sides are not quite the same. Each nerve crosses in front of the internal mammary artery of its own side, passing from its outer to its inner margin, and is crossed

by the subclavian vein. The nerve of the right side crosses the second part of the subclavian artery, the scalenus anticus intervening, and afterwards descends by the outer side of the right innominate vein. That of the left side is placed in front of the first portion of the left subclavian artery, and lower down crosses the arch of the aorta. Within the thorax both nerves descend on the sides of the pericardium, passing in front of the pulmonary roots. They then pierce the diaphragm, and on its under surface spread out into branches, which supply the muscle and form connections with twigs from the diaphragmatic plexus of the sympathetic nerves. In the upper part of the thorax the phrenic is usually joined by a twig from the sympathetic nerve, and sometimes receives filaments from the nerve to the subclavius muscle; less commonly it receives a communicating twig from the descending branch of the hypoglossal. On its way it detaches small twigs to the pericardium and pleura.

THE BRACHIAL PLEXUS.

The brachial plexus (Figs. 380, 381) is formed by the anterior divisions of the fifth, sixth, seventh, and eighth cervical nerves, and the larger part

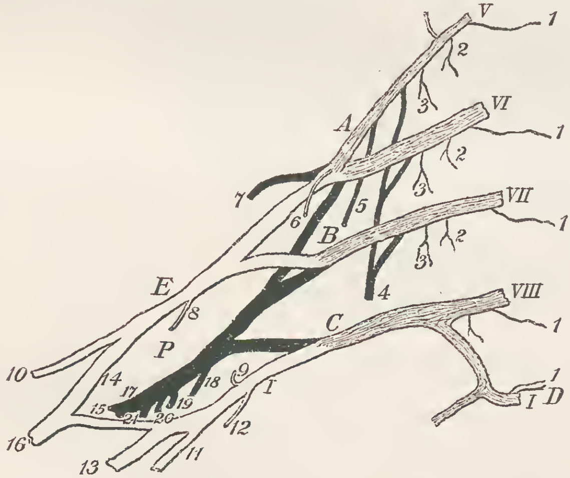

FIG. 381.—DIAGRAM OF THE BRACHIAL PLEXUS. *A*, First primary cord; *B*, second primary cord; *C*, third primary cord; *E*, external cord; *P*, posterior cord; *I*, inner cord. 1, Communicating branches to sympathetic; 2, branches to intertransverse and longus colli muscles; 3, branches to scalene muscles; 4, posterior thoracic nerve; 5, nerve to the rhomboids; 6, nerve to subclavius; 7, suprascapular nerve; 8, external anterior thoracic; 9, internal anterior thoracic; 10, external cutaneous; 11, internal cutaneous; 12, lesser internal cutaneous; 13, ulnar; 14, outer head of median; 15, inner head of median; 16, median; 17, musculo-spiral; 18, 19, 20, the three subscapular nerves; 21, circumflex. (J. Y. M.)

of that of the first dorsal nerve. The fifth cervical nerve usually receives a slender connection from the fourth. Each of the constituent trunks is connected with the gangliated cord of the sympathetic nerve by a com-

municating branch. The cervical nerves emerge between the intertransverse muscles and pass outwards in the plane between the scalenus anticus and scalenus medius; the portion of the first dorsal which joins the plexus ascends over the inner border and upper surface of the first rib. A little beyond the outer margin of the anterior scalene muscle the fifth and sixth nerves unite with one another to form an upper or *first* cord; the seventh nerve forms by itself a middle or *second* cord; the eighth cervical and first dorsal join with one another on the deep surface of the anterior scalene muscle to form a lower or *third* cord. The three primary cords, thus formed, pass outwards and downwards towards the apex of the axilla in company with the third part of the subclavian artery, the lower cord being placed behind the upper margin of the vessel, and the other two in close proximity.

As the nerve-cords are passing from the neck into the axilla, a re-arrangement of their fibres takes place. Each of the three primary cords divides into an anterior and posterior branch, and these branches unite with one another in such a way as to give rise to three new or secondary cords, which are named respectively the outer, inner, and posterior cord of the brachial plexus. The *outer cord* is formed by the anterior branches of the first and second primary cords. The *inner cord* is formed by the anterior branch of the third cord. The *posterior cord* is formed by the posterior branches of all of the three primary cords. Variations, for the most part of little consequence, occur in the formation of the secondary cords, the most usual being the contribution of a portion of the anterior division of the second primary cord to the formation of the inner cord.

The nerve-cords enter the axilla, and descend through its first part by the outer side of the axillary artery, but a little farther down a change in the relative positions of the structures takes place. The inner cord sweeping behind the artery gains its inner side, the posterior cord reaches the posterior surface of the artery, while the outer cord, approaching the vessel more closely, comes into contact with its outer side. In these positions the three cords descend for a little distance; but while still high in the axilla they break up into their terminal divisions. Some of the branches of the plexus take origin in the neck, most of them arise below the clavicle.

Branches of the Brachial Plexus in the Neck.

As the nerves emerge from the intervertebral foramina, they detach *small muscular branches* for the supply of the intertransverse, scalene, and longus colli muscles. The fifth cervical nerve is connected by a *communicating branch* with the phrenic nerve.

The **nerve to the rhomboids**, a long slender cord, takes origin from the back of the fifth cervical nerve; it pierces the middle scalene muscle and

passes downwards and outwards on the deep surface of the levator anguli scapulae to reach the posterior margin of the scapula, along which it descends on the deep surface of the rhomboid muscles; it supplies both rhomboid muscles, and detaches twigs to the levator anguli scapulae.

The **posterior thoracic nerve** (external respiratory nerve of Sir Charles Bell) arises by three roots which spring from the fifth, sixth, and seventh cervical nerves respectively; the roots separately pierce the middle scalene muscle and unite with one another on its posterior surface. The nerve descends through the apex of the axilla, behind the large structures which pass to and from the arm, and, continuing its course, passes downwards on the axillary surface of the serratus magnus, to which muscle it is entirely distributed.

The **nerve to the subclavius,** a slender thread, arises from the front of the first primary cord of the plexus and passes downwards, crossing in front of the third part of the subclavian artery, to enter the deep surface of the muscle; it frequently communicates by a small twig with the phrenic nerve.

The **suprascapular nerve,** a considerable offset, arises from the back of the first primary cord; it courses downwards and outwards to the upper border of the scapula, and passes through the suprascapular notch (beneath the ligament). It detaches a twig to the shoulder-joint, and supplies the supraspinatus and infraspinatus muscles, descending through the great scapular notch to reach the latter muscle.

Branches of the Brachial Plexus given off Below the Clavicle.

The **outer cord** gives off the *external anterior thoracic nerve,* and the *external cutaneous* or *musculo-cutaneous nerve,* and is continued as the *outer head of the median nerve.* The **inner cord** gives off the *internal anterior thoracic nerve,* the *lesser internal cutaneous nerve,* the *internal cutaneous nerve,* and the *ulnar nerve,* and is continued as the *inner head of the median nerve.* The **posterior cord** gives off *three subscapular nerves* and the *circumflex nerve,* and is continued as the *musculo-spiral nerve.* The branches of the posterior cord supply the integument and the muscles of the posterior aspect of the limb.

The **external anterior thoracic nerve** arises from the outer cord about the level of the clavicle. It passes forwards and inwards in front of the first part of the axillary artery, and breaks up into branches which pierce the costo-coracoid membrane, and supply the pectoralis major, entering the muscle on its deep surface; one branch crosses inwards and downwards in front of the artery and forms a connection with the internal anterior thoracic nerve.

The **internal anterior thoracic nerve** takes origin from the inner cord in the upper part of the axilla and passes forwards between the axillary artery and vein to gain the deep surface of the pectoralis minor; to

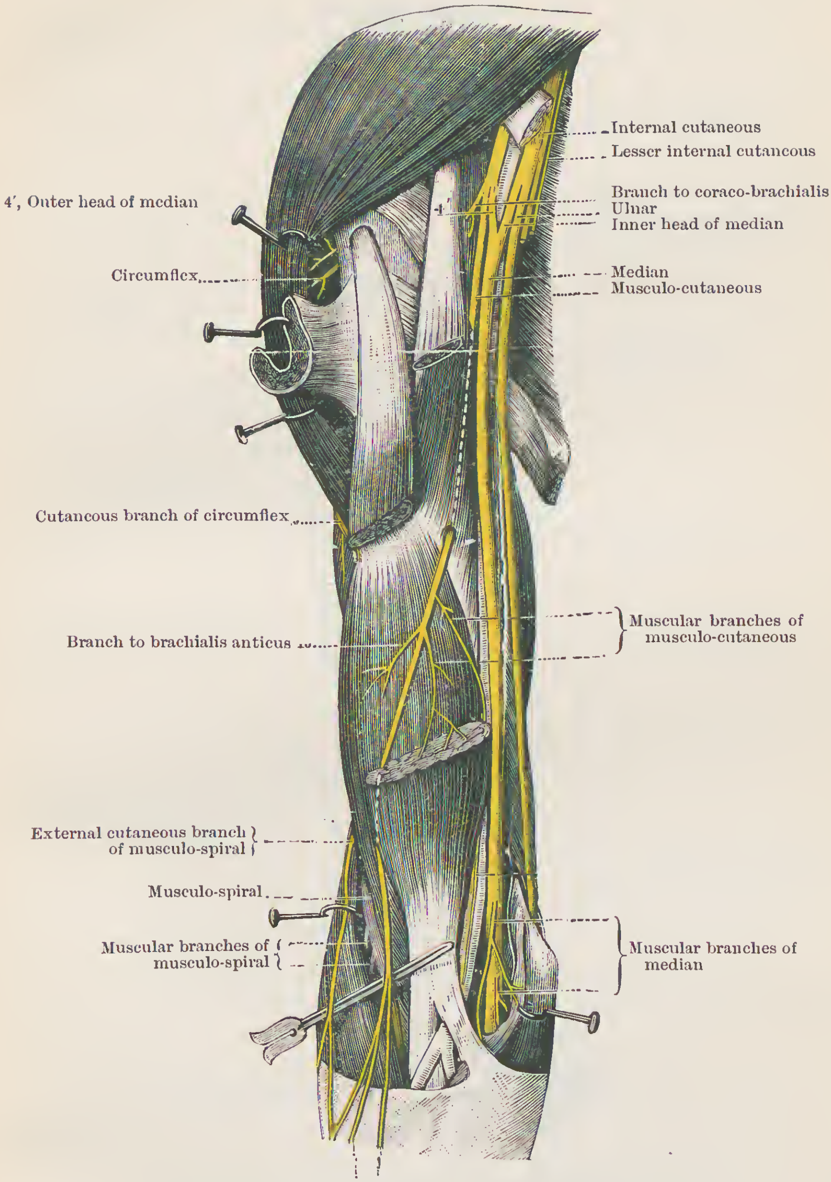

Fig. 382.—The Deep Nerves of the Front of the Arm. (L. Testut.)

To face p. 516.

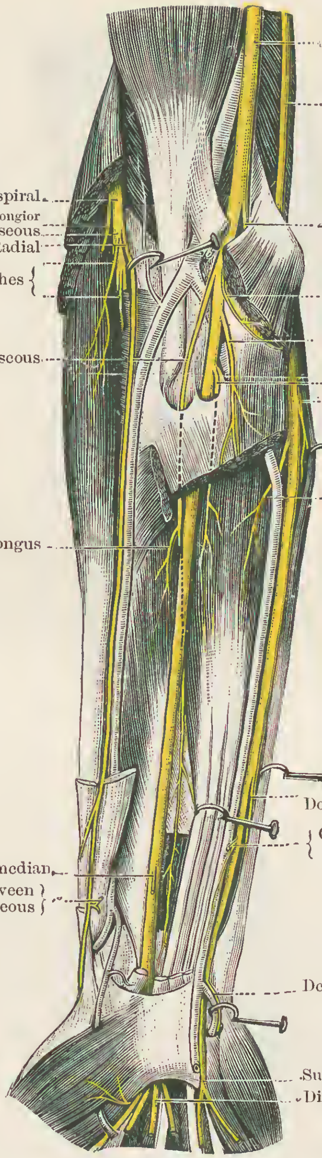

FIG. 383.—DEEP NERVES OF THE FOREARM. (L. Testut.)

To face p. 517.

which muscle it is chiefly distributed; one or two branches, however, pass through the pectoralis minor and terminate in the pectoralis major. Near its origin the trunk of the nerve is joined by a considerable communicating branch from the external anterior thoracic nerve.

The **musculo-cutaneous (external cutaneous) nerve** (Fig. 382) arises from the outer cord in the upper part of the axilla. It is directed downwards and outwards, pierces the coraco-brachialis, and descends in the upper arm between the biceps and the brachialis anticus; in this portion of its course it supplies the coraco-brachialis, biceps, and brachialis anticus muscles. It becomes subcutaneous a little above the level of the bend of the elbow at the outer edge of the biceps tendon, and immediately afterwards divides into an anterior and a posterior branch, both of which are entirely sensory in their distribution. They supply the integument of the anterior and posterior surfaces of the radial side of the forearm. The posterior, the smaller, reaches as far as the wrist; the anterior communicates above the wrist with the radial nerve, and distributes its terminal filaments to the skin over the thenar eminence.

The **lesser internal cutaneous nerve** (nerve of Wrisberg) arises from the inner cord at about the same level as the internal anterior thoracic nerve; it passes downwards and inwards, crossing at first behind the axillary vein, to pierce the fascia in the upper third of the arm. It supplies the integument of the inner and posterior region of the arm, reaching as far as the elbow, and gradually passing backwards as it descends. It is of variable size and ramifies in front of the intercosto-humeral nerve, with which it is closely associated in its distribution, the two stems being usually connected in the axilla by communicating branches.

The **internal cutaneous nerve** takes origin from the inner cord, immediately below the nerve of Wrisberg, and descends by the inner and anterior margin of the artery to about the middle of the upper arm, where it pierces the fascia and divides into an anterior and posterior branch. In the axilla it detaches one or two small branches which supply the integument of the inner region of the upper part of the arm. The anterior and posterior terminal branches descend along the anterior and posterior borders respectively of the inner side of the forearm, supplying the skin as far as the level of the wrist. The anterior branch frequently communicates, a little above the wrist, with a cutaneous twig of the ulnar nerve.

The **ulnar nerve** (Figs. 382-386), a trunk of large size, takes origin from the inner cord, immediately below the internal cutaneous nerve. It descends at first by the inner side of the main artery between it and the vein. In the upper third of the arm it gradually separates from the artery and passes backwards to pierce the internal intermuscular septum. Continuing its course it descends behind the septum, passes between the inner epicondyle and the olecranon, and enters the forearm between the heads of the flexor carpi ulnaris. It then descends in a straight line upon the sur-

face of the flexor digitorum profundus to the wrist, being deeply placed at first behind the flexor carpi ulnaris, but afterwards lying, with the ulnar artery, at the outer edge of the tendon of that muscle. It crosses the wrist, passing on the outer side of the pisiform bone, in front of the anterior annular ligament, and terminates on entering the hand by dividing into a superficial and a deep branch.

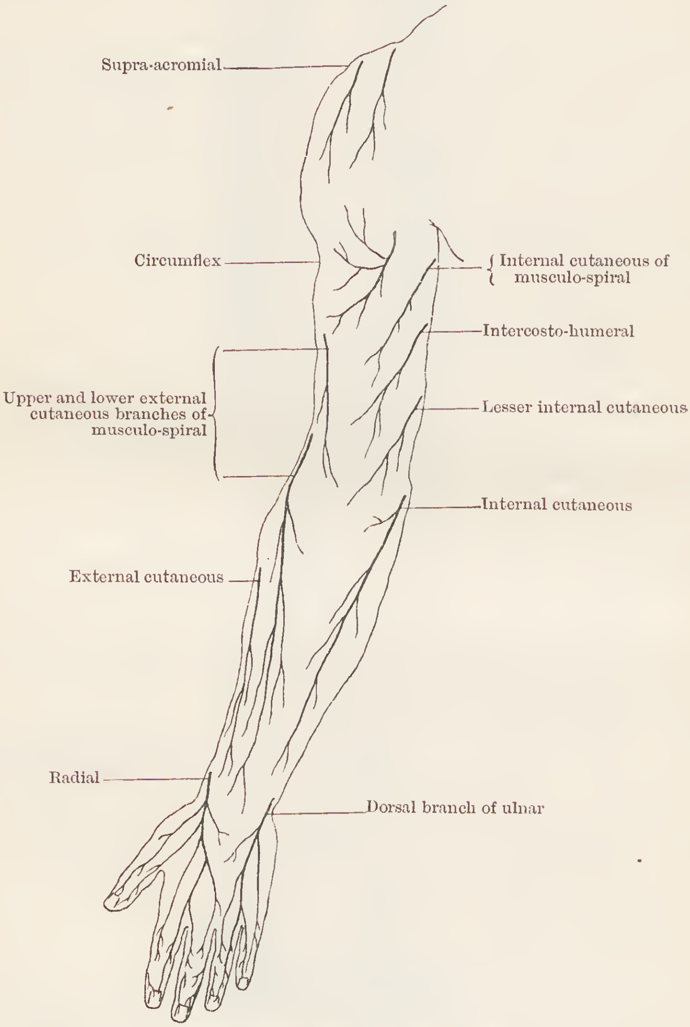

FIG. 384.—DIAGRAM OF THE CUTANEOUS NERVES OF THE POSTERIOR SURFACE OF THE UPPER LIMB. (J. Y. M.)

No branches are given off in the arm; but as the nerve passes the elbow-joint one or two *articular filaments* are detached.

Branches in the forearm. Muscular branches are supplied to the flexor carpi ulnaris and the inner half of the flexor digitorum profundus. *Two*

anterior cutaneous offsets are detached to the skin of the lower part of the front of the forearm and the inner part of the palm ; the higher of the two, forms a communication with the internal cutaneous nerve, the other accompanies the ulnar artery to the hand. The *dorsal branch* leaves the parent trunk about two inches above the elbow-joint, and, passing backwards on the

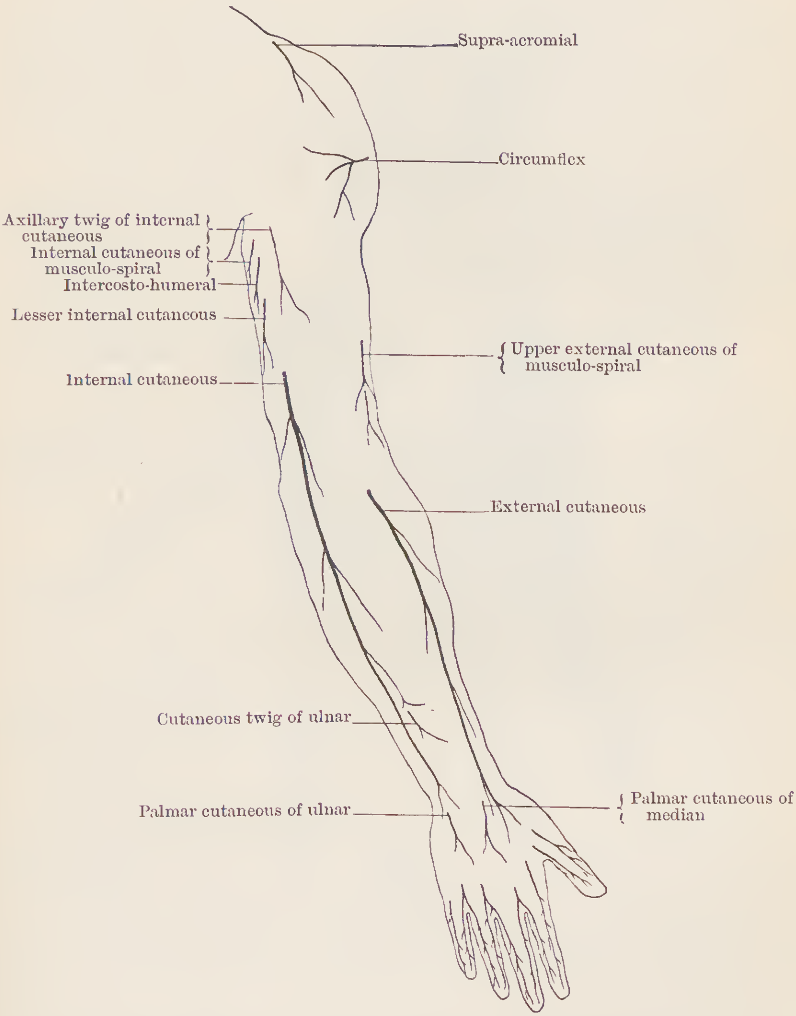

FIG. 385.—DIAGRAM OF THE CUTANEOUS NERVES OF THE ANTERIOR SURFACE OF THE UPPER LIMB. (J. Y. M.)

deep surface of the tendon of the flexor carpi ulnaris, pierces the fascia and breaks up into branches which supply the inner area of the back of the hand and furnish the dorsal digital nerves for both sides of the little finger and the inner side of the ring finger ; its terminal twigs form con-

nections with branches of the radial nerve and assist in the supply of the outer side of the ring and the inner side of the middle fingers.

Branches in the hand. *The superficial division* furnishes a twig to the palmaris brevis and some small cutaneous offsets, and then divides into two branches, the inner of which becomes the palmar digital nerve for the inner side of the little finger, while the outer forms a connection with the median nerve and divides into branches for the contiguous sides of the little and ring fingers. *The deep division*, muscular in its distribution, passes backwards among the muscles of the little finger and crosses outwards in the palm in company with the deep palmar arch; it supplies the muscles of the little finger, the two inner lumbricales, all the interossei, the adductor pollicis, and the inner head of the flexor pollicis brevis.

The **median nerve** (Figs. 382, 386), continued from the outer and inner cords of the plexus, is formed in the third part of the axilla, the inner head crossing in front of the artery to join the outer head. In the arm the nerve, descending with the artery, is placed at first by the outer side of the vessel, but afterwards passes in front of it, and finally gains its inner side. In the forearm it passes between the heads of the pronator teres, and descends on the deep surface of the flexor digitorum sublimis. At the wrist it lies at the outer edge of the tendons of the superficial flexor. In entering the hand, it passes in front of the tendons and behind the anterior annular ligament, at the lower border of which it splits into an external and internal division. No branches are given off in the arm, but at the level of the elbow some *articular filaments* are detached.

Branches in the forearm. Separate *muscular branches* are supplied to the pronator teres, flexor carpi radialis, palmaris longus, and flexor digitorum sublimis. The *anterior interosseous nerve* descends with the anterior interosseous artery, supplies the inner half of the flexor profundus, the flexor pollicis longus, and the pronator quadratus, and furnishes an articular filament to the wrist. A small *palmar cutaneous branch* arises a little above the wrist, and passes in front of the annular ligament to supply the outer portion of the palm.

Branches in the hand. The outer terminal division first detaches a *muscular branch* which supplies those short muscles of the thumb, which are placed externally to the tendon of the flexor pollicis longus, viz. the abductor, the opponens, and the outer head of the flexor pollicis brevis; it then divides into two branches, the outer of which furnishes *the palmar digital nerves for both sides of the thumb*, while the inner, after furnishing a muscular *twig to the outer lumbricalis*, becomes the *palmar digital nerve for the outer side of the index finger.* The inner terminal division divides into two branches; the outer gives a muscular *twig to the second lumbricalis* and divides into *palmar digital branches for the contiguous sides of the index and middle fingers*; the inner branch forms a connection with the ulnar nerve and splits to form the *digital branches for the contiguous sides of the middle and ring fingers.*

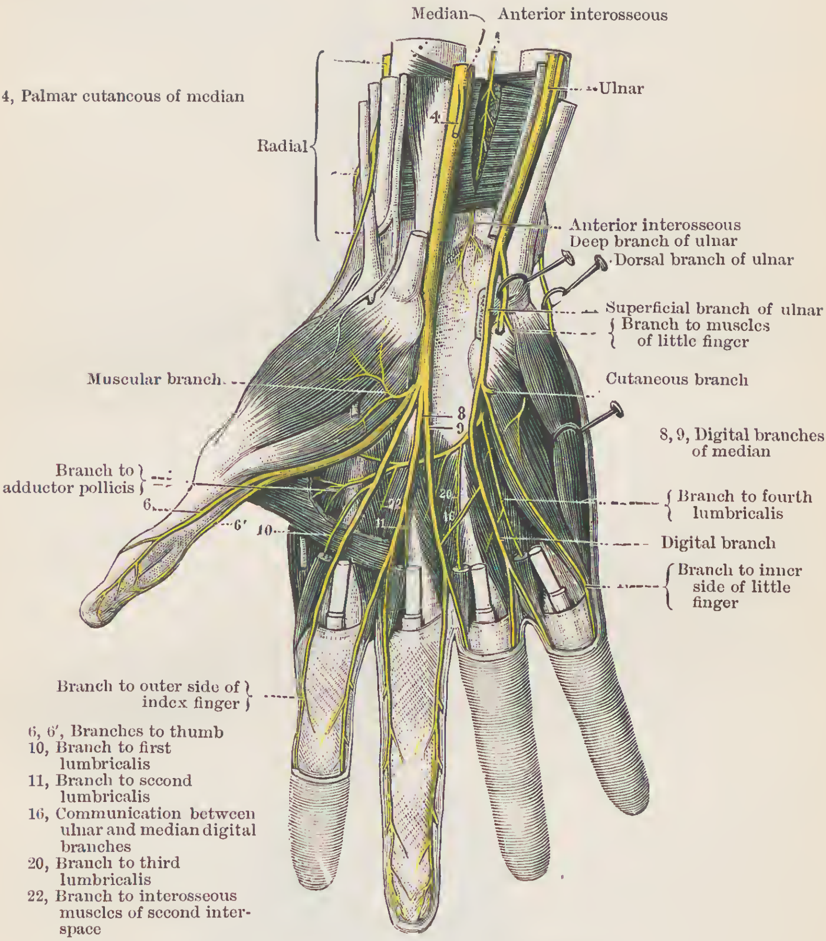

FIG. 386.—NERVES OF THE PALM. (L. Testut.)

To face p. 520.

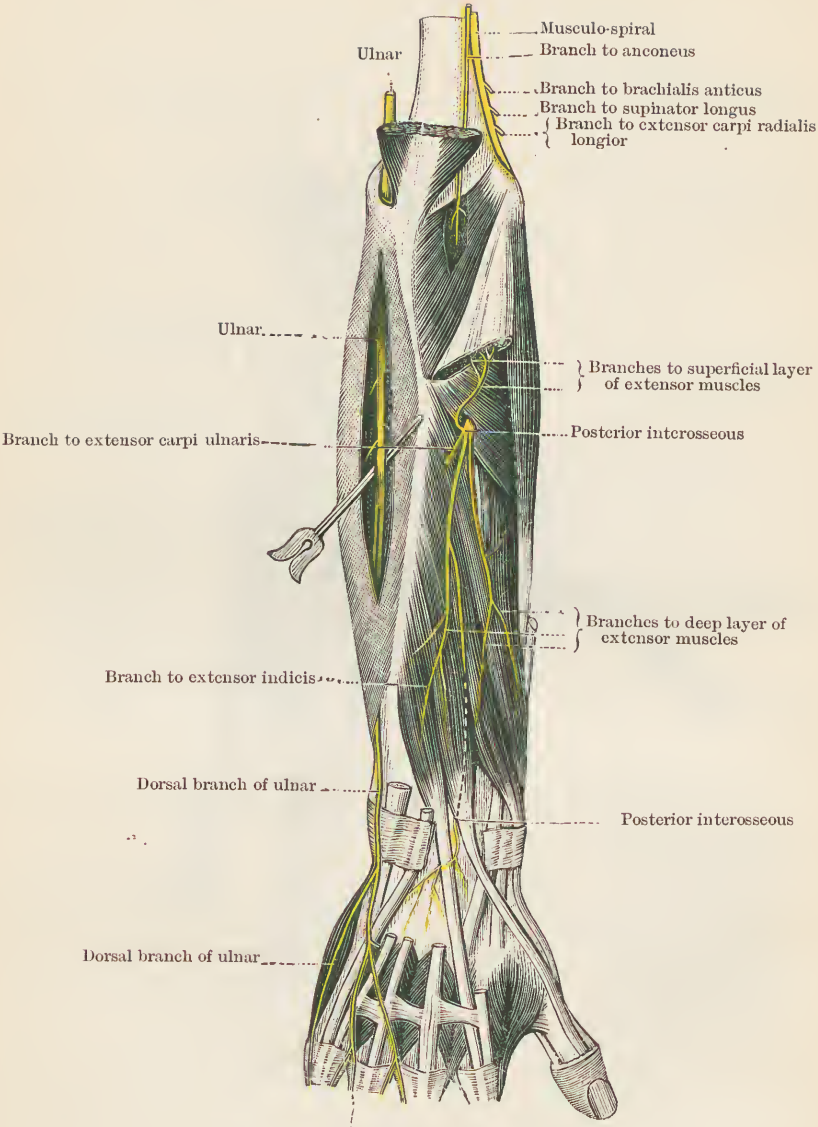

FIG. 387.—THE POSTERIOR INTEROSSEOUS NERVE. (L. Testut.)

To face p. 521.

The *palmar digital* nerves, the series of which is completed by the branches of the ulnar nerve, descend farther on the fingers than do the dorsal nerves. They lie in front of the arteries and reach almost to the tips. They supply the palmar surfaces of the digits, and give branches posteriorly, which assist in the supply of the dorsal surfaces. In each finger the offsets of the palmar nerves ramify in the matrix of the nail; in the index and middle fingers, and the outer side of the ring finger, branches of the palmar nerves form the chief supply of the integument covering the dorsal surfaces of the second and third phalanges.

The **three subscapular nerves** (Fig. 380) are derivatives of the posterior cord, and take origin in the axilla. They supply the muscles of the posterior wall of the axilla. The first or *short subscapular* supplies the subscapularis; the second, middle, or *long subscapular* ramifies on the deep surface of the latissimus dorsi; the third or *lowest subscapular* detaches a twig to the lower border of the subscapularis, and is distributed to the teres major.

The **circumflex nerve** arises from the posterior cord, immediately below the lowest subscapular. It accompanies the posterior circumflex artery, and breaks up into its branches on the deep surface of the deltoid muscle. A slender *articular filament* passes upwards to the shoulder-joint; *muscular branches* supply the deltoid and teres minor, that for the teres minor being remarkable for the presence of a gangliform swelling. A number of *cutaneous branches* pierce the deltoid and ramify over its lower part; one, larger than the others, descends along the posterior border of the deltoid, detaches some recurrent branches which ramify over the muscle, and supplies the skin of the outer and posterior region of the arm for a little distance below the deltoid insertion.

The **musculo-spiral nerve** (Figs. 382, 387), the continuation of the posterior cord of the plexus, is the largest nerve of the limb. In the axilla it descends behind the main artery, but in the upper third of the arm it inclines inwards, and, with the superior profunda artery, passes between the outer and inner heads of the triceps. It then follows the course of the musculo-spiral groove, pierces the external intermuscular septum, and descends under cover of the supinator longus and extensor carpi radialis longior, between them and the brachialis anticus, to the level of the external epicondyle, where it splits into its terminal divisions, the radial and posterior interosseous nerves. It detaches cutaneous and muscular branches.

The *internal cutaneous branch*, a slender twig, arises from the upper part of the main trunk; extending nearly to the elbow, it is distributed to the integument of the inner area of the posterior surface of the arm, behind the region supplied by the intercosto-humeral nerve. The *upper external cutaneous branch*, detached as the main trunk sweeps round the outer border of the humerus, pierces the fascia in the line of the external intermuscular septum, and extends as far as the elbow, supplying the skin of the outer and anterior region of the lower part of the arm. The *lower external cutaneous branch*, considerably larger than the upper, and arising in company with it, or

immediately below it, passes downwards to gain the posterior surface of the forearm. Reaching as far as the wrist, it supplies the skin of the lower part of the outer region of the arm, and of the back of the forearm.

The *muscular branches* supply the triceps, anconeus, supinator longus, and extensor carpi radialis longior muscles, and a small twig enters the brachialis anticus. One of the branches for the lower part of the inner head of the triceps (the ulnar collateral nerve of Krause) springs from the upper part of the trunk and descends through the internal intermuscular septum within the sheath of the ulnar nerve; the nerve to the anconeus, also given off high up, is a long slender trunk which descends through the substance of the inner head of the triceps. The nerves to the supinator longus and extensor carpi radialis longior and the twig to the brachialis anticus spring from the lower part of the main trunk.

The **radial nerve** (Figs. 383, 388), the smaller of the terminal branches of the musculo-spiral, descends in the forearm at first under cover of the fleshy belly of the supinator longus and afterwards along the posterior edge of its tendon. It pierces the fascia a little above the wrist and passes on to the back of the hand, where it detaches a number of branches to the integument of the dorsal surface and breaks up into digital branches. The branches to the dorsum of the hand supply the skin of the outer area, and some of them sweeping round the radial border are distributed to the outer part of the thenar eminence. The *dorsal digital nerves* supply both sides of the thumb, the index and middle fingers, and in most cases the outer side of the ring finger. The series of dorsal digital nerves is completed by the offsets of the dorsal branch of the ulnar nerve. Communications between the branches of the two main trunks take place at the bases of the middle and ring fingers, and the number of the digital branches from each source is subject to variation. Although the radial nerve is in most cases entirely cutaneous in its distribution, occasionally a branch is detached to the abductor pollicis muscle.

The dorsal digital nerves descend on the fingers behind the arteries. In the case of the thumb, the little finger, and the inner side of the ring finger, they supply the integument as far as the base of the nail; in the other cases they do not as a rule pass beyond the distal extremities of the first phalanges, the supply of the integument being completed by the palmar digital branches.

The **posterior interosseous nerve** (Fig. 387), the larger terminal division of the musculo-spiral, passes backwards round the neck of the radius, in the substance of the supinator brevis, to gain the dorsal surface of the forearm, where it descends at first between the superficial and deep layers of muscles, and afterwards on the posterior surface of the interosseous membrane. At the wrist, much reduced in size, it passes with the tendons of the extensor digitorum communis and extensor indicis along the broad groove on the back of the radius; on the back of the carpus it terminates in a gangliform swelling, from which branches pass to the wrist and to the

articulations of the hand. The branches which it detaches on its course are entirely muscular, and supply all the muscles, superficial and deep, of the back of the forearm, with the exception of the supinator longus, the extensor carpi radialis longior, and the anconeus. The muscles to which it is distributed are—the supinator brevis and the extensores carpi radialis brevior, digitorum communis, minimi digiti, carpi ulnaris, ossis metacarpi pollicis, primi internodii pollicis, secundi internodii pollicis, and indicis.

THE THORACIC NERVES.

The thoracic nerves are twelve in number. The first eleven are usually called *intercostal nerves*, the twelfth is named the *last dorsal*. They do not unite with one another to form plexuses, but course independently round the body wall and terminate as the anterior cutaneous nerves of the thorax and abdomen. On their way they supply the muscles, and give off lateral cutaneous branches. Each nerve is connected to a corresponding ganglion of the sympathetic chain by two branches, one of which has the characteristic appearance of a spinal nerve, the other that of a sympathetic nerve. The upper six trunks course in the wall of the thorax; the lower six, in an increasing degree in succession from above downwards, traverse the abdominal wall before terminating in their anterior cutaneous twigs.

The **upper six intercostal nerves.** The *first nerve* is of large size, but its greater part immediately passes upwards in front of the hinder part of the first rib to join the brachial plexus; the remainder of the nerve passes onwards as an intercostal trunk. Each nerve passes behind the sympathetic chain, and in front of the external intercostal muscle, and at first, in the region where the internal intercostal muscle is deficient, lies immediately behind the pleura. Further outwards it passes between the two layers of the intercostal muscles, and occupies the subcostal groove, lying, except in the case of the first two or three, below the companion artery. More anteriorly it sinks into the substance of the internal intercostal muscle, and finally gains its deep surface, crossing in front of the triangularis sterni muscle and the internal mammary artery.

The *anterior cutaneous branches* are of small size. They pierce the thoracic wall by the side of the sternum, and are chiefly directed outwards to supply the integument over the great pectoral muscle. That of the first nerve is frequently absent.

The *lateral cutaneous branches* arise between the intercostal muscles, and run forwards for a little distance with the main trunks. Passing outwards they pierce in succession the wall of the thorax along a line drawn vertically downwards immediately behind the anterior wall of the axilla, and reach the surface between the digitations of the serratus magnus. The first nerve usually gives off no lateral branch. The lateral branch of the second nerve is known as the *intercosto-humeral nerve* (Fig. 380); it is of large size, is directed outwards and backwards through the axilla, where it forms communications with the nerve of Wrisberg, and is distributed to the

integument of the inner and posterior part of the arm, reaching nearly to the elbow. The remaining lateral branches divide, before reaching the surface, into anterior and posterior twigs, which ramify subcutaneously, and form connections in front with the supraclavicular and anterior cutaneous nerves, and behind with the cutaneous offsets of the posterior primary divisions. The posterior cutaneous twig of the third nerve is large, and supplies the integument of the base of the axilla, forming connections with the intercosto-humeral nerve.

The *muscular branches* supply the levatores costarum, the external and internal intercostal muscles, the serratus posticus superior, and the triangularis sterni.

The **lower five intercostal nerves.** These are at first similar in course to the upper nerves; eventually, however, they enter the abdominal wall and run forwards between the internal oblique and transversalis muscles. The *anterior cutaneous branches*, somewhat irregular, reach the surface in a double row by the outer and inner borders of the rectus. The *lateral cutaneous branches* appear between the digitations of the external oblique muscle, and divide like the majority of those of the higher nerves into anterior and posterior twigs. The *muscular branches* supply the levatores costarum, the external and internal intercostal muscles, the serratus posticus inferior, the transversalis, the rectus, the internal oblique, and the external oblique.

The **last dorsal nerve** passes outwards in company with the first lumbar artery, escaping below the ligamentum arcuatum externum, crossing anteriorly the quadratus lumborum muscle, and piercing the posterior tendon of the transversalis muscle. Its subsequent course is similar to that of one of the lower intercostal nerves. The *lateral branch* does not divide into two, but, piercing the external oblique some little distance above its insertion, is continued downwards over the iliac crest, a little behind the anterior superior spine, and supplies the integument of the anterior part of the gluteal region. The other branches are similar to those of one of the lower intercostal nerves.

THE LUMBAR PLEXUS.

The lumbar plexus (Figs. 389, 390) is formed in front of the transverse processes, in the substance of the psoas muscle, from the anterior divisions of the first four lumbar nerves. The first receives a slender branch from the last dorsal nerve, and detaches a connecting branch to the second lumbar; the second, third, and fourth break up into branches which form the roots of the chief derivatives of the plexus; the fourth gives off a connecting branch, which descends to the fifth and assists in forming the lumbo-sacral cord. Each of the nerves is joined by communicating branches from the lumbar ganglia of the sympathetic chain. The branches of the plexus are the ilio-hypogastric, the ilio-inguinal, the genito-crural, the external cutaneous, the anterior crural, the obturator, and, in occasional

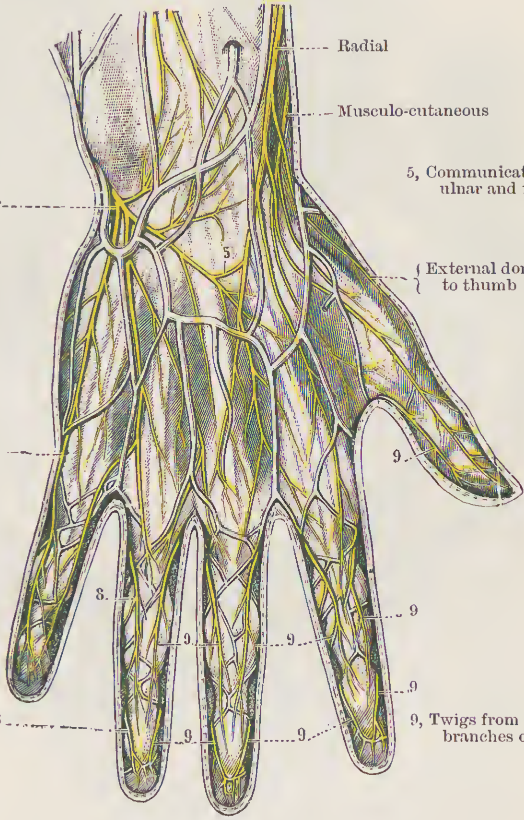

FIG. 388.—NERVES OF THE DORSUM OF THE HAND. (L. Testut.)

To face p. 524.

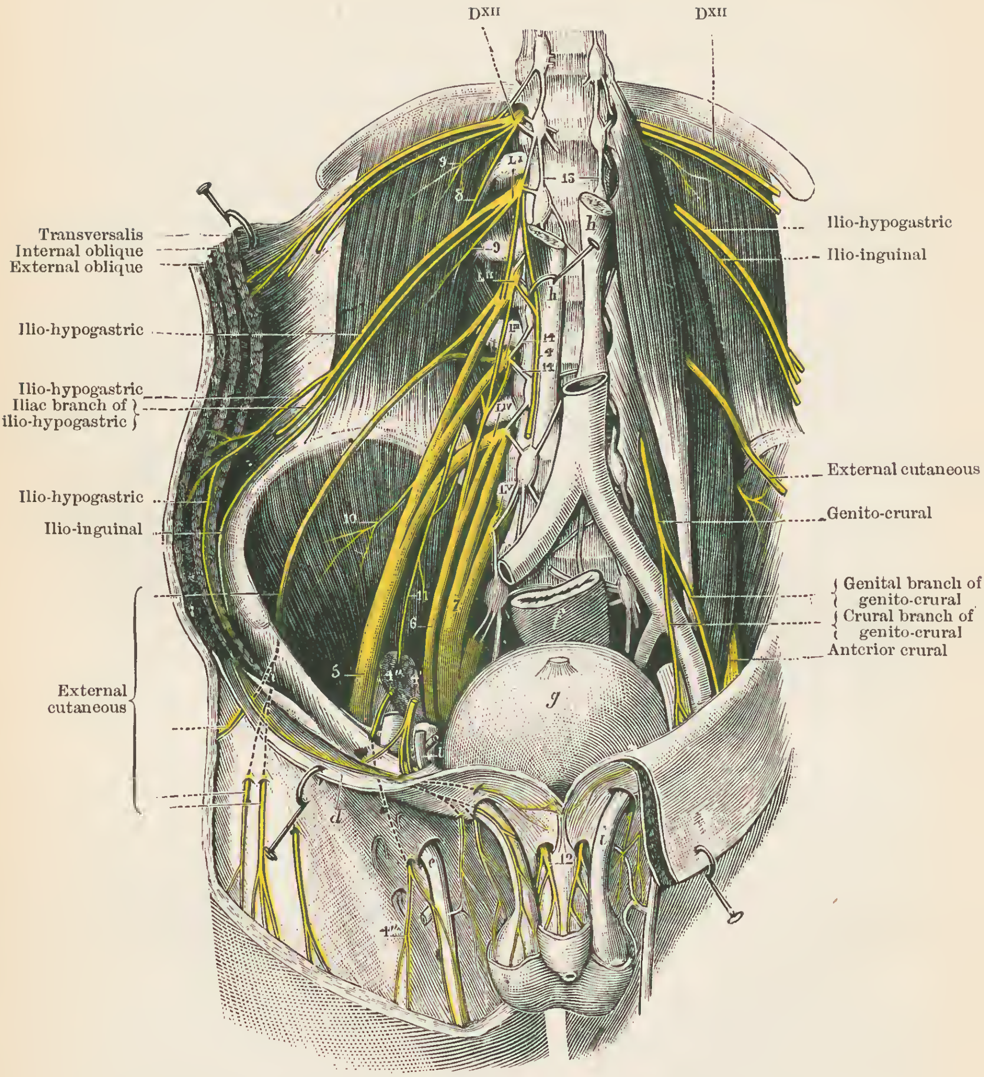

FIG. 389.—THE BRANCHES OF THE LUMBAR PLEXUS. The psoas has been removed on the right side. *d*, Tendon of external oblique; *e*, internal saphenous vein; *f*, rectum; *g*, bladder; *h*, crura of diaphragm; *i*, spermatic cord; 4, genito-crural; 4′, genital branch of genito-crural; 4″, crural branch of genito-crural; 5, anterior crural; 6, obturator; 7, lumbo-sacral cord; 8, branch from last dorsal to first lumbar nerve; 9, branches to quadratus lumborum; 10, branch to iliacus; 11, accessory obturator; 12, dorsal nerve of penis; 13, gangliated cord of sympathetic; 14, communicating branches with sympathetic. (L. Testut.)

To face p. 525.

circumstances, the accessory obturator; in addition, from the first three trunks small twigs are detached to the psoas and quadratus muscles.

The ilio-hypogastric and the ilio-inguinal arise by a common trunk from the first lumbar nerve; the genito-crural takes origin by separate roots from the second and third; the obturator springs from the anterior parts of the second, third, and fourth nerves; the external cutaneous arises from the posterior parts of the second and third nerves; the anterior crural is derived from the posterior parts of the second, third, and fourth; the accessory obturator, when present, springs by one or more roots from the obturator nerve or from the lower part of the plexus.

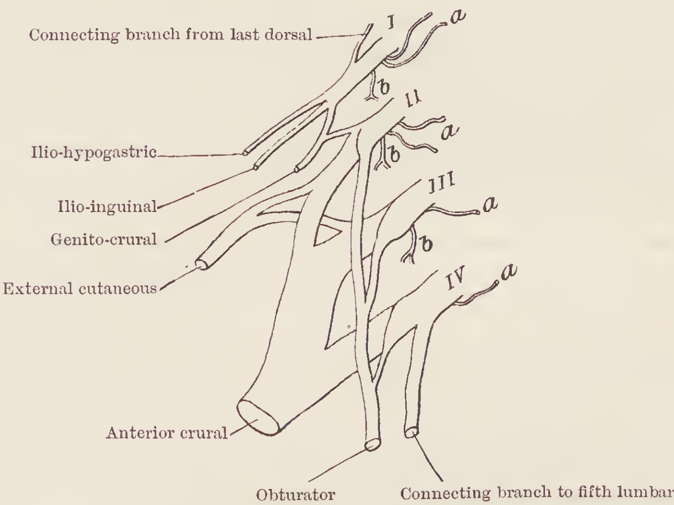

FIG. 390.—DIAGRAM OF THE LUMBAR PLEXUS. *a*, Communicating branches to sympathetic; *b*, to psoas and quadratus muscles. (J. Y. M.)

The **ilio-hypogastric nerve** emerges from the outer border of the psoas, and, descending obliquely towards the iliac crest, crosses in front of the quadratus lumborum; it then pierces the transversalis and detaches its iliac or lateral branch. The remainder of the nerve courses forwards and downwards, passing through the internal oblique, and finally emerges as an *anterior cutaneous* nerve, about an inch above the superficial abdominal ring. *Muscular branches* are supplied to the three broad muscles of the abdominal wall, and to the rectus and the pyramidalis; *connecting twigs* pass to the ilio-inguinal and occasionally to the last dorsal. The *iliac branch*, after piercing the internal and external oblique muscles, crosses the crest of the ilium about two inches behind the anterior superior spine. Its branches, which all pass to the integument, descend as far as the level of the great trochanter, forming connections with those of the lateral branch of the last dorsal nerve in front, and the posterior divisions of the lumbar nerves behind.

The **ilio-inguinal nerve** is more slender than the ilio-hypogastric, beneath

and in close proximity to which it emerges from the psoas, crosses the quadratus lumborum, and courses through the abdominal wall. It becomes subcutaneous by passing through the superficial abdominal ring. *Muscular branches* are detached to the three broad muscles. The *terminal twigs* are distributed to the scrotum or labium, and to the upper and inner part of the thigh. Occasionally the ilio-hypogastric and ilio-inguinal nerves are united for a considerable distance into one trunk.

The **genito-crural nerve** emerges on the anterior surface of the psoas, either as a single trunk or already divided. It descends in front of the muscle, and splits at a variable spot into its terminal divisions. The *genital division* accompanies the spermatic vessels along the inguinal canal, and supplies the cremaster muscle. The *crural division* descends in front of the external iliac vessels, enters the thigh, and finally, by the outer margin of the femoral artery, about two inches below Poupart's ligament, pierces the fascia lata; its terminal twigs supply the integument of the upper and anterior part of the thigh, and form connections with those of the middle and internal cutaneous branches of the anterior crural nerve.

The **external cutaneous nerve** emerges at the outer border of the psoas, a little below the level of the ilio-inguinal nerve. It crosses in front of the iliacus and, in close proximity to the anterior superior spine, passes behind Poupart's ligament; in the thigh it immediately breaks up into anterior and posterior branches. The *posterior branch*, the smaller, passes backwards, pierces the fascia near the outer margin of the gluteus maximus, and distributes its offsets to the integument of the posterior and outer part of the upper two-thirds of the thigh. The *anterior branch*, passing downwards, pierces the deep fascia three or four inches below Poupart's ligament, and ramifies over the outer part of the thigh, supplying the skin as far at the level of the knee, some of the terminal twigs reaching the patellar plexus.

The **obturator nerve** emerges from the inner border of the psoas, and courses forwards along the wall of the true pelvis to the obturator canal, lying immediately above the obturator vessels. Near the place of exit from the pelvis it divides into anterior and posterior branches. The *anterior branch* passes through or over the obturator externus, and descends in the thigh on the anterior surface of the adductor brevis, and behind the pectineus and adductor longus. At the lower border of the adductor longus it forms communications with the long saphenous and internal cutaneous nerves; it usually terminates as a cutaneous twig, piercing the fascia at the anterior border of the gracilis, about half-way down the thigh. It supplies muscular branches to the adductor longus and gracilis, and occasionally to the adductor brevis and pectineus.

The *posterior branch* pierces the obturator externus and descends in the thigh behind the adductor brevis. It supplies muscular offsets to the obturator externus, adductor brevis, and adductor magnus, and furnishes

a small branch which enters the hip-joint through the cotyloid notch. It terminates in a long slender nerve, which descends to the knee-joint, coursing first in the substance of the adductor magnus, then lying by the inner side of the artery in the popliteal space, and finally piercing the posterior ligament.

The *accessory obturator nerve*, when present, descends along the inner margin of the psoas, crosses in front of the superior ramus of the pubis, and joins the anterior division of the main nerve or terminates in the pectineus.

The **anterior crural nerve** (Figs. 389, 394), the largest offset of the plexus, emerges from the outer border of the psoas, a little below the level at which the external cutaneous nerve escapes. It descends in the groove between the psoas and iliacus, passes behind Poupart's ligament, and, immediately after entering the thigh, breaks up, by the outer side of the femoral artery, into its terminal branches. Within the abdomen it furnishes a number of twigs to the iliacus. The terminal branches are divided into two groups, one of which is mainly cutaneous in its distribution, the other chiefly muscular. The first or more superficial group comprises the internal and middle cutaneous nerves and the nerves to the sartorius. The deeper group is formed of the nerves to the pectineus and quadriceps, and one cutaneous nerve, the long saphenous.

The *nerve to the pectineus*, a slender twig, is directed inwards behind the femoral artery and enters the anterior surface of the muscle. The *nerves to the sartorius*, usually two or three in number, are at first incorporated with the middle cutaneous trunk; they enter the upper part of the muscle. The *nerves to the rectus femoris*, one or two in number, pass directly to the deep surface of the muscle in its upper part; from one of them a branch is usually directed backwards to the hip-joint. The *nerves to the vasti and crureus muscles* form a number of large branches which descend for a considerable distance on the surface of the muscles which they supply; terminally they furnish twigs to the knee-joint.

The *middle cutaneous nerve* divides, close to its origin, into two branches which usually pierce the fascia lata separately, about four inches below Poupart's ligament; the outer generally traverses the sartorius muscle, while the inner crosses in front of it. They supply the integument of the lower two-thirds of the front of the thigh, their terminal branches reaching the patellar plexus.

The *internal cutaneous nerve*, in its descent, gradually crosses the femoral artery in front. In the upper part of the thigh it detaches a number of twigs which reach the surface by the side of the internal saphenous vein. About the middle of the thigh it divides into an anterior and a posterior branch. The anterior branch, the larger, descends by the anterior border of the sartorius, pierces the fascia in the lower third of the thigh, supplies the integument in the vicinity of the inner side of the knee, and furnishes branches to the patellar plexus. The posterior branch,

after forming connections with the internal saphenous and obturator nerves, descends by the posterior border of the sartorius, perforates the fascia about the level of the knee-joint, and distributes its branches to the upper part of the inner side of the leg.

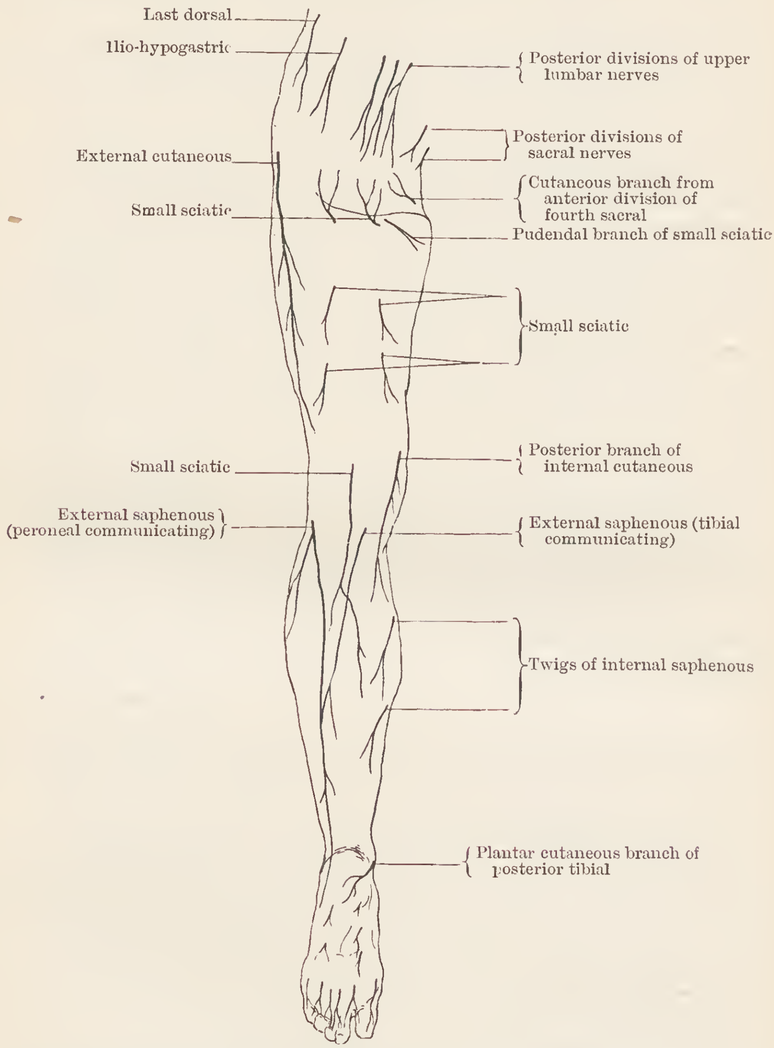

FIG. 391.—DIAGRAM OF THE DISTRIBUTION OF THE CUTANEOUS NERVES UPON THE POSTERIOR SURFACE OF THE LOWER LIMB. (J. Y. M.)

The *internal saphenous nerve*, in its descent, gradually approaches the femoral artery; in the middle third of the thigh the nerve accompanies the artery in Hunter's canal, lying in front of it and a little to its outer side. When the artery passes backwards into the popliteal space, the nerve, continuing its straight course, descends on the deep surface of the sartorius, and finally pierces the fascia below the level of the knee,

emerging between the tendons of the sartorius and gracilis. In the thigh the nerve furnishes twigs which, uniting with branches of the obturator and the posterior division of the internal cutaneous nerve, constitute the *subsartorial plexus.* A little above the level of the knee a considerable

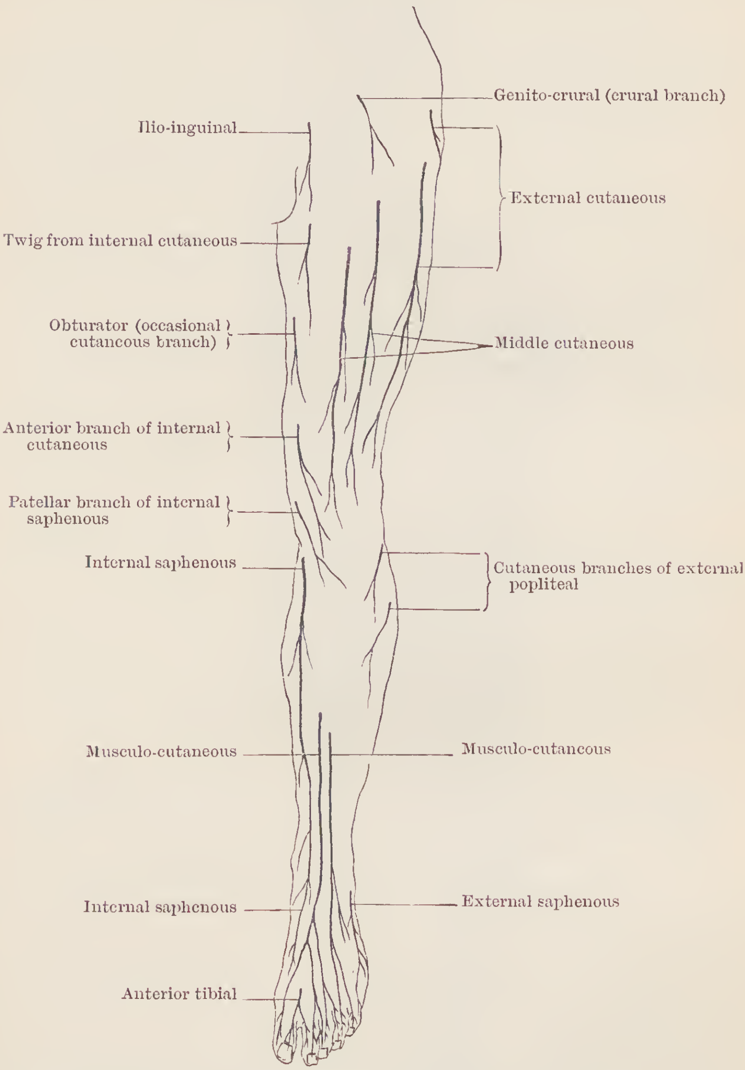

FIG. 392.—DIAGRAM OF THE DISTRIBUTION OF THE CUTANEOUS NERVES UPON THE ANTERIOR SURFACE OF THE LOWER LIMB. (J. Y. M.)

branch is detached which, piercing the sartorius, turns outwards and ramifies in front of and below the patella, forming along with branches of the external, middle, and internal cutaneous nerves, the *patellar plexus.* In the leg the internal saphenous nerve descends in the superficial fascia, by the side of the internal saphenous vein, and supplies the skin of the inner

region. At the ankle it passes in front of the internal malleolus. Its terminal branches communicate with offsets of the musculo-cutaneous nerve, and ramify upon the inner side of the metatarsal region of the foot.

THE SACRAL PLEXUS.

The sacral plexus (Fig. 395) is formed by the union with one another of the lumbo-sacral cord (which results from the junction of the descending branch of the fourth with the fifth lumbar nerve), and the first, second, third, and a portion of the fourth sacral trunks. These are chiefly continued

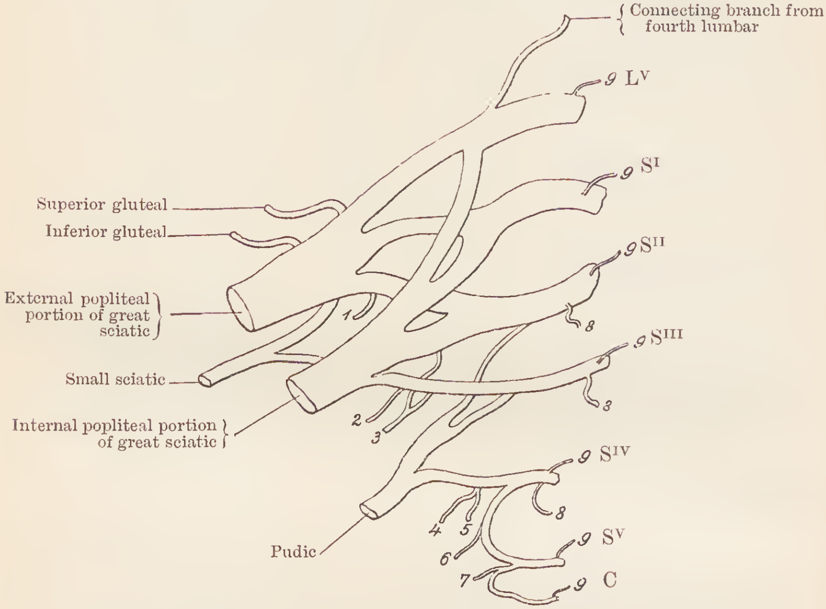

Fig. 393.—Diagram of the Sacral and Coccygeal Plexuses. 1, To pyriformis; 2, to quadratus femoris; 3, to obturator internus; 4, cutaneous branch of fourth sacral; 5, muscular branch of fourth sacral; 6, 7, muscular and cutaneous branches of coccygeal plexus; 8, visceral branches; 9, communicating branches with sympathetic. The great sciatic is represented as split up into its terminal branches. (J. Y. M.)

into two nerves, the great sciatic above and the pudic below, but several subsidiary branches are also given off. The great sciatic, the largest nerve of the body, is formed from the larger parts of the lumbo-sacral cord, and the first, second, and third sacral trunks; in it may be distinguished two portions, one more anterior which eventually becomes the internal popliteal nerve, the other more posterior destined to become the external popliteal nerve. The pudic nerve, much smaller than the great sciatic, is formed from portions of the third and fourth trunks, and frequently receives a fasciculus from the second. The subsidiary nerves are—the superior gluteal which springs from the back of the lumbo-sacral cord and the first sacral trunk; the inferior gluteal from the back of the first and second sacral trunks; the small sciatic from the back of the second and third sacral trunks; the nerve to the pyriformis from the second or third sacral trunk; the nerve

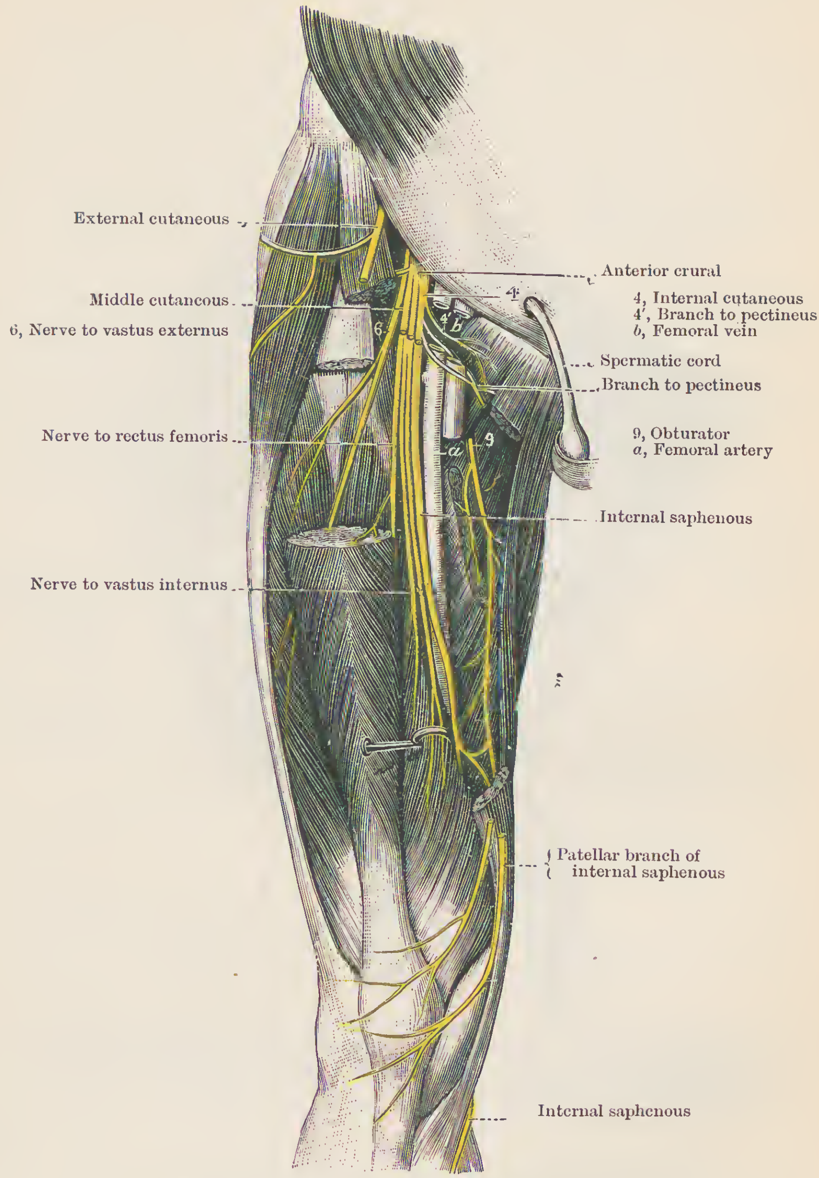

FIG. 394.—DEEP NERVES OF THE FRONT OF THE THIGH. (L. Testut.)

To face p. 530.

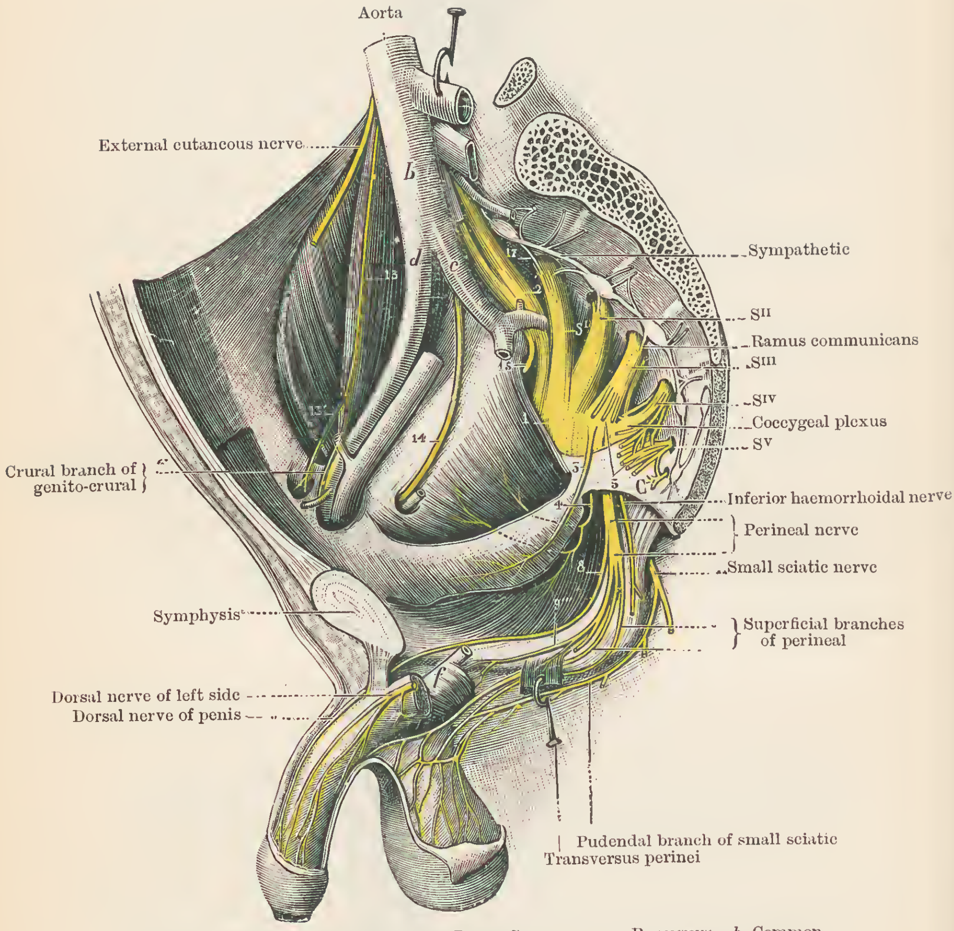

FIG. 395.—THE SACRAL PLEXUS OF THE RIGHT SIDE WITH ITS BRANCHES. *b*, Common iliac artery; *c*, internal iliac artery; *d*, external iliac artery; *f*, bulb; 1, great sciatic nerve; 2, lumbo-sacral cord; 3, a branch to levator ani; 4, nerve to obturator internus; 5, visceral branches; 8, dorsal nerve of penis; 9‴, deep branches of perineal; 13, genito-crural nerve; 13′, genital branch of genito-crural; 14, obturator nerve; 15, superior gluteal nerve; 18, rami communicantes. (L. Testut.)

To face p. 531.

to the obturator internus from the second and third sacral trunks; the nerve to the quadratus femoris from the third sacral trunk; and some visceral branches from the second, third, and fourth sacral trunks.

The lumbo-sacral cord descends over the base of the sacrum; the other trunks escape by the anterior sacral foramina. Uniting with one another, they rest upon the pyriformis muscle, and all the branches, with the exception of the visceral nerves and the nerve to the pyriformis, escape from the pelvis by the great sacro-sciatic foramen. The lumbo-sacral cord and the first two sacral trunks are of large size, the third and fourth sacral are comparatively small. Each of the trunks is connected with the sympathetic by a short branch of communication.

The **superior gluteal nerve** (Fig. 396), from the lumbo-sacral cord and the first sacral trunk, escapes through the great sacro-sciatic foramen, above the pyriformis muscle, in company with the gluteal artery. It ramifies between the gluteus medius and minimus, supplying them both, and sends its terminal branch forwards through their conjoined anterior margins to the tensor vaginae femoris.

The **inferior gluteal nerve**, from the first and second sacral trunks, escapes with the sciatic artery below the pyriformis muscle; it breaks up into numerous branches which supply the gluteus maximus, entering it on its deep surface. It is frequently partially incorporated with the small sciatic nerve.

The **small sciatic nerve**, from the second and third sacral trunks, is cutaneous in its distribution. It leaves the pelvis below the pyriformis, and descends along the middle line of the posterior surface of the limb, as far as the calf of the leg. After escaping from the cover of the gluteus maximus it descends in the thigh beneath the fascia lata, and becomes subcutaneous at the level of the knee. It distributes from both sides numerous branches to the integument, and near its termination communicates with the short saphenous nerve. Four or five branches of considerable size turn backwards at the inferior border of the gluteus maximus muscle and end in the skin of the lower part of the gluteal region. One offset, *the pudendal branch*, courses inwards and forwards below the tuberosity of the ischium to the scrotum or labium.

The **nerve to the obturator internus**, from the second and third sacral trunks, escapes below the pyriformis along with the pudic artery, and bending round the ischial spine re-enters the pelvis by the small sacro-sciatic foramen to reach the inner surface of the muscle. On its way it supplies a twig to the gemellus superior.

The **nerve to the quadratus femoris**, from the third sacral trunk, escaping below the pyriformis, passes downwards on the deep surface of the gemelli muscles, the lower of which it supplies on its way. It enters the quadratus on the deep surface.

The **pudic nerve** (Fig. 395), derived from the third and fourth sacral trunks, and occasionally from the second, escapes below the pyriformis,

and, in company with the pudic artery, by the inner side of which it is placed, bends round the small sacro-sciatic ligament to reach the ischio-rectal fossa, at the posterior extremity of which it breaks up into three branches. The three branches, along with the artery, continue their course forwards for some distance on the outer wall of the fossa in a canal formed by the obturator fascia.

The most posterior of the three, the *inferior haemorrhoidal*, separates itself from its neighbours in the hinder part of the fossa; it is directed downwards, forwards, and inwards, and breaks up into numerous twigs, which, travelling through the fatty tissue, reach the external sphincter muscle and the integument around the anus.

The second branch, the *perineal nerve*, pierces the wall of the canal a little further forwards, and breaks up into superficial and deep branches, respectively cutaneous and muscular in their distribution. The superficial branches, two in number, the *external and internal superficial perineal nerves*, run forwards, passing through or beneath the superficial transverse muscle. They break up, as they traverse Colles's fascia, into numerous long slender twigs, the branches of which form communications with those of the pudendal and inferior haemorrhoidal nerves; they supply the skin of the anterior part of the perineal space and the scrotum or labium. The deep branch of the perineal nerve, or *deep perineal nerve*, supplies the levator ani, transversus perinei, compressor urethrae, bulbo-cavernosus or sphincter vaginae, and the ischio-cavernosus, and furnishes a twig to the bulb.

The third main branch, the *dorsal nerve of the penis* or *clitoris*, accompanies the artery to its termination, lying above it in the anterior part of the fossa, by its outer side between the layers of the triangular ligament, and below and external to it in the terminal portion of its course. It supplies, in passing, a branch to the corpus cavernosum, and ramifies freely on the integument of the penis; in the female it is much smaller than in the male, and ramifies on the clitoris.

THE GREAT SCIATIC NERVE.

The great sciatic nerve (Fig. 396) escapes from the pelvis through the great sacro-sciatic foramen, below the lower border of the pyriformis muscle, and passes downwards, resting in succession upon the gemellus superior, obturator internus, gemellus inferior, quadratus femoris, and adductor magnus, to a little beyond the middle of the thigh, where it divides into the internal and external popliteal nerves. In the upper part of its course, on the deep surface of the gluteus maximus, it lies between the ischial tuberosity and the great trochanter, being placed a little nearer to the former than the latter prominence; further on it is covered posteriorly by the long head of the biceps muscle. The place of division is variable, and may be found at any spot in the upper two-thirds of the thigh; and occasionally the internal and external popliteal nerves spring directly from

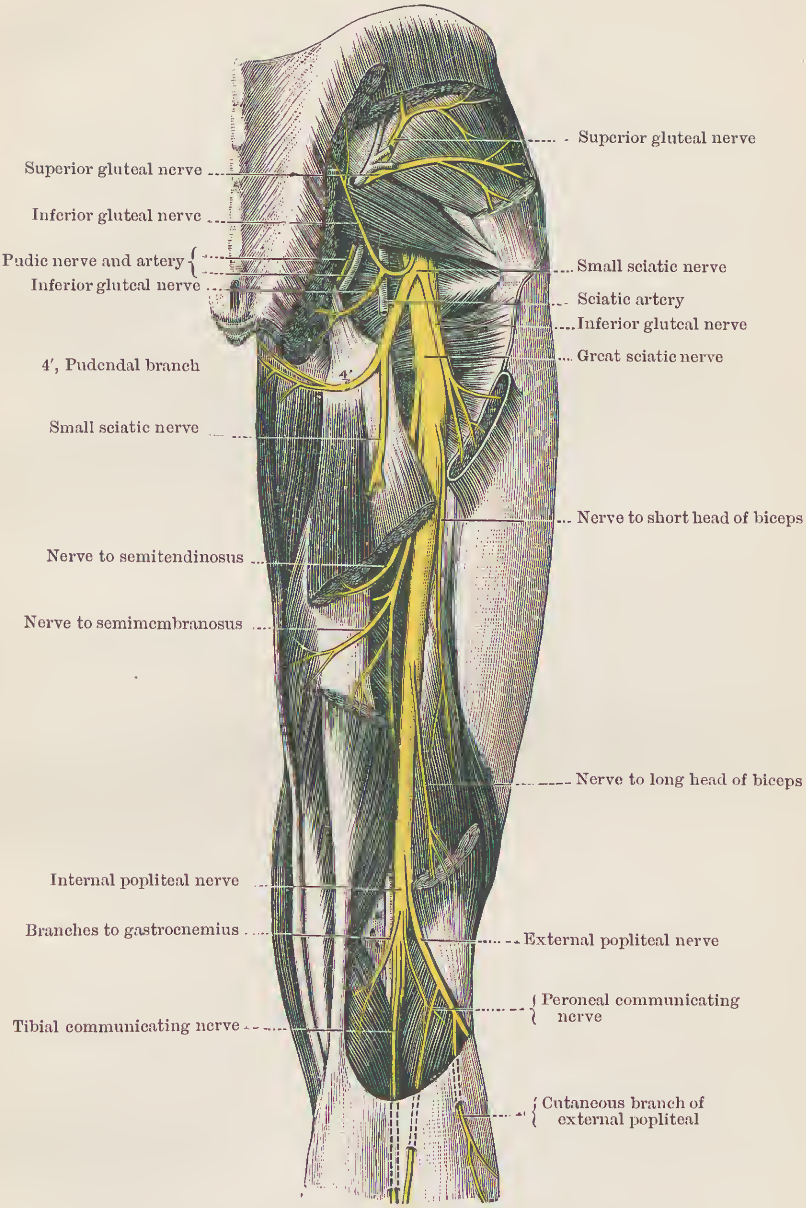

FIG. 396.—DEEP NERVES OF THE BACK OF THE HIP AND THIGH. (L. Testut.)

To face p. 532.

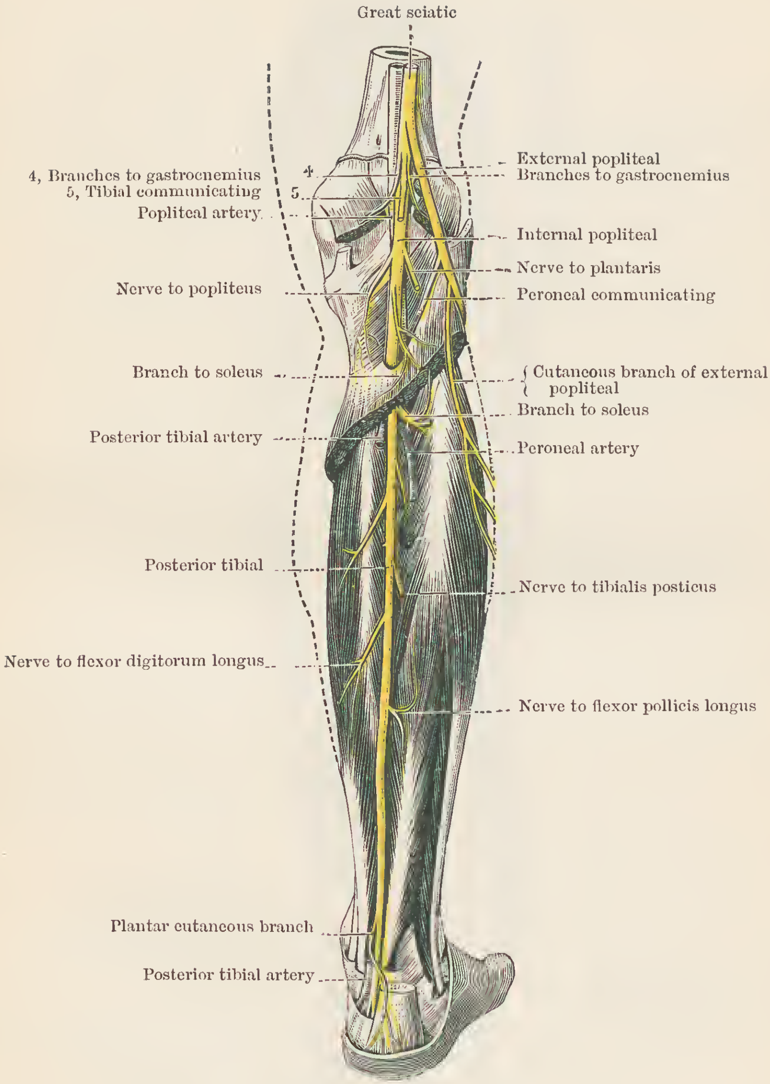

FIG. 397.—DEEP NERVES OF THE BACK OF THE LEG. (L. Testut.)

To face p. 533.

the plexus. The great sciatic nerve, or, when it is split at or near its origin, the inner of the two divisions, furnishes *muscular branches* to the semimembranosus, semitendinosus, and both heads of the biceps, and gives an additional twig to the adductor magnus.

THE INTERNAL POPLITEAL (THE TIBIAL) NERVE.

The internal popliteal nerve (Fig. 396), the larger of the two divisions, continuing the straight course of the parent trunk, descends along the middle line of the popliteal space, at the lower end of which, passing under cover of the soleus, it becomes the posterior tibial nerve. It is the most superficial of the large structures contained in the space, and is at first external to the main artery; but afterwards, crossing it superficially, it is placed by its inner side. It detaches one cutaneous, three articular, and several muscular branches.

The cutaneous branch, the *tibial communicating nerve*, is one of the roots of the external saphenous nerve; it descends on the surface of the gastrocnemius and underneath the fascia to the lower third of the leg, where, becoming subcutaneous, it is joined by the peroneal communicating branch from the external popliteal nerve. The resulting trunk, the *external or short saphenous nerve*, passes behind and below the outer malleolus and runs forwards on the outer side of the foot, forming communications with the musculo-cutaneous nerve, and supplying terminally the outer side of the little toe. Occasionally its area of supply is extended to the dorsum of the foot and to the third and fourth toes; the peroneal communicating branch is sometimes very small, the external saphenous nerve being in these circumstances mainly continued from the tibial communicating trunk.

The *articular branches*, three in number, and of small size, accompany the superior and inferior internal, and the azygos articular arteries respectively. Their terminal twigs pierce the capsular ligament of the knee.

The *muscular branches* supply both heads of the *gastrocnemius*, the *plantaris*, the *soleus*, and the *popliteus*. The branch to the last-named muscle descends on its posterior surface, and turns round its lower border to enter it anteriorly.

The **posterior tibial nerve** (Fig. 397) accompanies the posterior tibial artery, and divides terminally, between the internal malleolus and the heel, into the internal and external plantar nerves. It is at first internal to the vessels, but afterwards crossing behind them, descends by their outer border. It supplies *muscular branches* to the soleus, tibialis posticus, flexor digitorum longus, and flexor pollicis longus. A cutaneous twig, the *calcaneo-plantar nerve*, is detached from the lower part of the trunk; it pierces the internal annular ligament and ramifies in the skin of the heel and of the inner side of the posterior part of the sole. One or two small *articular filaments* are described as passing from the posterior tibial nerve to the ankle-joint.

The **internal plantar nerve** (Fig. 398), the larger of the divisions of the posterior tibial, is comparable in its distribution to the median nerve in the hand. Concealed at first by the abductor hallucis, it afterwards runs forwards between that muscle and the flexor digitorum brevis, furnishing branches to both, and detaching a number of cutaneous twigs, which appear superficially along the line of the internal intermuscular septum. Opposite the base of the first metatarsal bone it gives off the plantar cutaneous branch for the inner side of the great toe, which nerve on its way forwards detaches a twig to the flexor hallucis brevis muscle.

About the middle of the foot the internal plantar nerve breaks up into three digital branches. The first furnishes a twig to the first lumbricalis muscle, and divides into plantar branches for the contiguous sides of the first and second toes. The second divides into branches for the contiguous sides of the second and third toes; it occasionally supplies the second lumbricalis muscle. The third, after receiving a communicating branch from the external plantar nerve, supplies the contiguous sides of the third and fourth toes. The plantar digital nerves supply the plantar surfaces of the toes, and each detaches a dorsal branch which ramifies under the nail.

To sum up, the internal plantar nerve supplies *muscular branches* to the flexor digitorum brevis, the abductor hallucis, the flexor hallucis brevis, the first lumbricalis, and, occasionally, the second lumbricalis. Its *cutaneous branches* (*a*) ramify on the inner portion of the sole, and (*b*) form the plantar digital nerves of the first, second, and third toes, and the inner side of the fourth.

The **external plantar nerve** (Fig. 398), comparable to the ulnar in the hand, is directed obliquely outwards in the sole between the flexor brevis digitorum and the flexor accessorius, in company with the external plantar artery. It supplies on its way muscular branches to the flexor accessorius and abductor minimi digiti muscles, and furnishes one or two cutaneous twigs, which reach the surface along the line of the external intermuscular septum. Opposite the base of the fifth metatarsal bone it divides into a superficial and a deep branch.

The superficial branch divides into outer and inner portions. The outer portion detaches offsets to the flexor minimi digiti brevis, and, as a rule, to the interosseous muscles of the fourth space, and is afterwards continued as the plantar cutaneous nerve of the outer side of the little toe. The inner branch, after giving off a slender twig to join the outermost digital branch of the internal plantar nerve, divides to supply the contiguous sides of the fourth and fifth toes.

The deep branch of the external plantar nerve bends forwards and inwards, in company with the plantar arterial arch, on the deep surface of the flexor tendons. It is entirely muscular in its distribution, supplying the three outer lumbricales, the interosseous muscles of the three inner spaces, the adductor hallucis, and the transversus pedis.

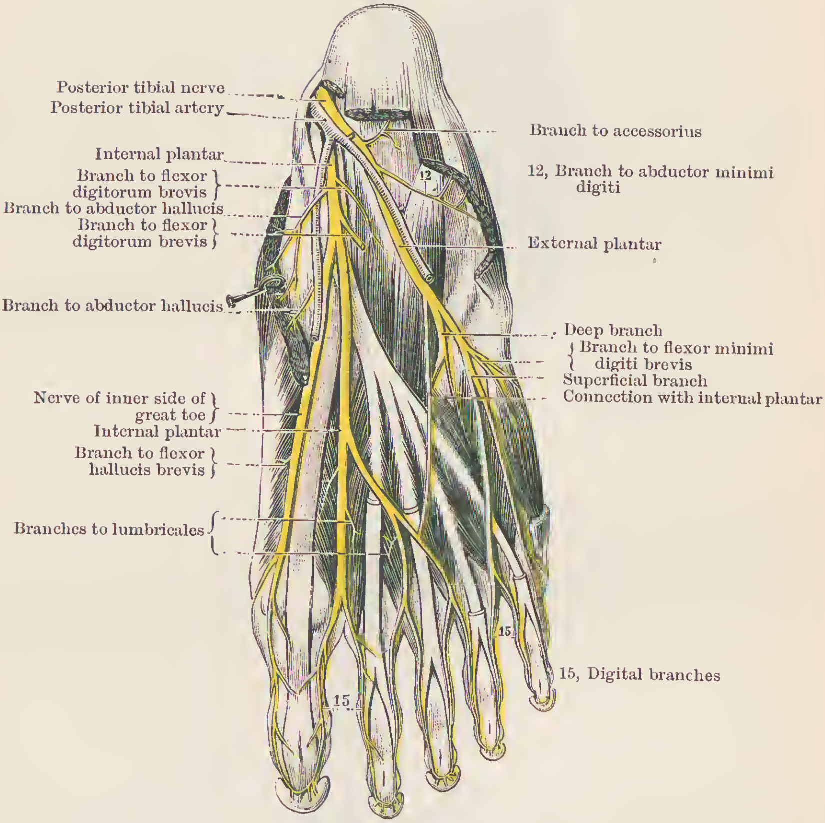

FIG. 398.—DEEP NERVES OF THE SOLE. (L. Testut.)

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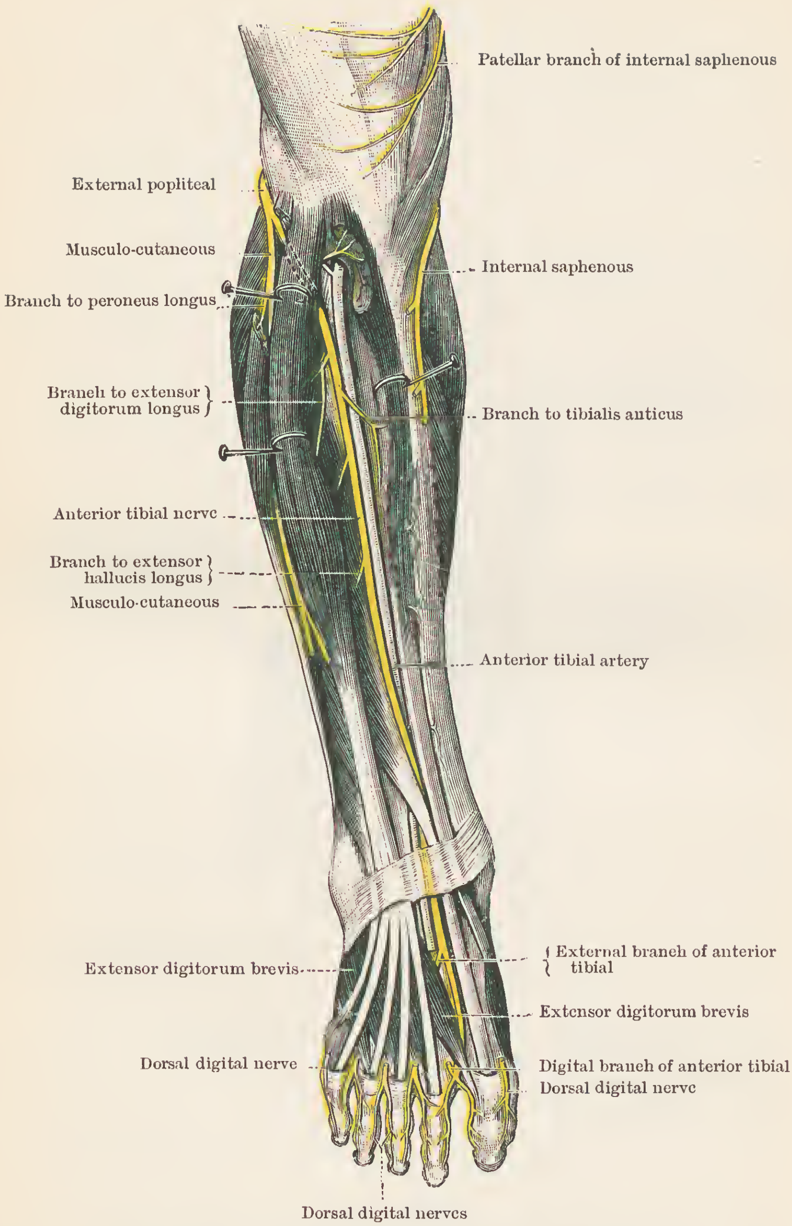

Fig. 399.—Deep Nerves of the Front of the Leg. (L. Testut.)

To face p. 535.

The *muscular branches* of the external plantar supply the following muscles: flexor accessorius, abductor minimi digiti, flexor minimi digiti brevis, transversus pedis, adductor hallucis, all the interosseous muscles, and the two or three outer lumbricales. The *cutaneous branches* (*a*) ramify on the outer region of the sole, and (*b*) form the plantar digital nerves of the little toe and the outer side of the fourth.

THE EXTERNAL POPLITEAL (THE PERONEAL) NERVE.

The external popliteal (Fig. 396) descends along the outer margin of the popliteal space, at first under cover of the biceps muscle and afterwards along the inner edge of its tendon. Immediately below the head of the fibula, it bends forwards, pierces the origin of the peroneus longus, and divides into its terminal branches, the musculo-cutaneous and anterior tibial nerves. On its way it detaches two cutaneous and three articular offsets.

Of the *cutaneous branches* one, the smaller, supplies the skin of the outer and posterior region of the upper part of the leg; the other, the *peroneal communicating*, joins the tibial communicating in the lower third of the leg to form the external saphenous nerve.

The *articular branches* are small: two of them accompany the external articular arteries to the knee; the third, the recurrent articular branch, arising near the termination of the parent trunk, is directed upwards, through the tibialis anticus, to the joint.

The **musculo-cutaneous nerve** (Fig. 399), one of the terminal divisions of the external popliteal, descends between the peronei and extensor digitorum longus, supplying on its way the peroneus longus and brevis, and furnishing some slender cutaneous offsets. A little below the middle of the leg it pierces the fascia and divides into an outer and an inner branch.

The *outer branch* detaches filaments to the skin of the front of the leg, ramifies over the outer side of the dorsum of the foot, forming communications with the internal branch on the one side and the external saphenous nerve on the other, and terminates in dorsal digital branches for the contiguous sides of the fifth and fourth and the fourth and third toes; its area of supply is occasionally diminished in extent by the encroachment, from the outer side, of the external saphenous nerve.

The *inner branch* detaches filaments to the front of the leg and ramifies over the inner side of the dorsum, communicating on the one side with the outer branch and on the other with the internal saphenous nerve; it terminates usually in three branches. The inner of these supplies the inner side of the great toe, the second joins the terminal twig of the anterior tibial nerve which supplies the contiguous sides of the first and second toes, the third supplies the contiguous sides of the second and third toes. The dorsal digital nerves (Fig. 400) supply the integument in each case as far as the base of the nail; they are very variable in their mode of origin.

The **anterior tibial nerve** (Fig. 399) passes forwards and downwards from the place of division of the external popliteal, and traverses the origin of the extensor digitorum longus muscle to gain the anterior surface of the interosseous membrane. Continuing its course it descends at first by the outer side of the anterior tibial artery, and afterwards in front of it, and in company with the vessel reaches the dorsum of the foot, passing behind the anterior annular ligament; a little below the ligament it divides into external and internal branches. On its way it detaches *muscular offsets* to the tibialis anticus, extensor digitorum longus, extensor hallucis longus, and peroneus tertius, and gives one or two *articular filaments* to the ankle-joint.

The *external branch* bends outwards over the tarsus on the deep surface of the extensor digitorum brevis; it supplies the short extensor muscle, and, after becoming swollen like the posterior interosseous nerve of the upper limb, terminates in filaments which are distributed to the articulations of the foot.

The *internal branch*, continuing the course of the parent trunk, passes onwards under cover of the innermost division of the short extensor muscle, and along the first interosseous space, at the extremity of which, after receiving a communicating branch from the inner division of the musculo-cutaneous nerve, it divides into the dorsal branches for the contiguous sides of the first and second toes.

THE FOURTH SACRAL NERVE.

A small portion of the anterior division of this nerve enters, as already described, into the formation of the sacral plexus. Another small portion passes downwards to join the coccygeal plexus. The remainder of the nerve breaks up into visceral, muscular, and cutaneous branches. The *visceral branches* are small, and pass to the pelvic plexus of the sympathetic; they are associated with a few similar branches from the second and third sacral nerves. The *muscular branch* passes between the coccygeus and levator ani, detaching twigs to both, and reaches the external sphincter of the anus, in the supply of which it assists. The *perforating* or *cutaneous branch* pierces the great sacro-sciatic ligament, turns round the lower border of the gluteus maximus, and supplies the integument at the margin of the coccyx.

The **coccygeal plexus** (Fig. 393) is formed of two small loops, the anterior division of the fifth sacral nerve being joined from above by the descending branch from the fourth, and from below by the anterior division of the coccygeal nerve. The fifth sacral and the coccygeal before becoming connected with one another traverse the substance of the sacro-sciatic ligaments, and pierce the coccygeus muscle. From the plexus some minute *visceral branches* are detached; a slender *muscular twig* enters the coccygeus. A *cutaneous branch* pierces the coccygeus and ramifies in the skin over the back of the coccyx.

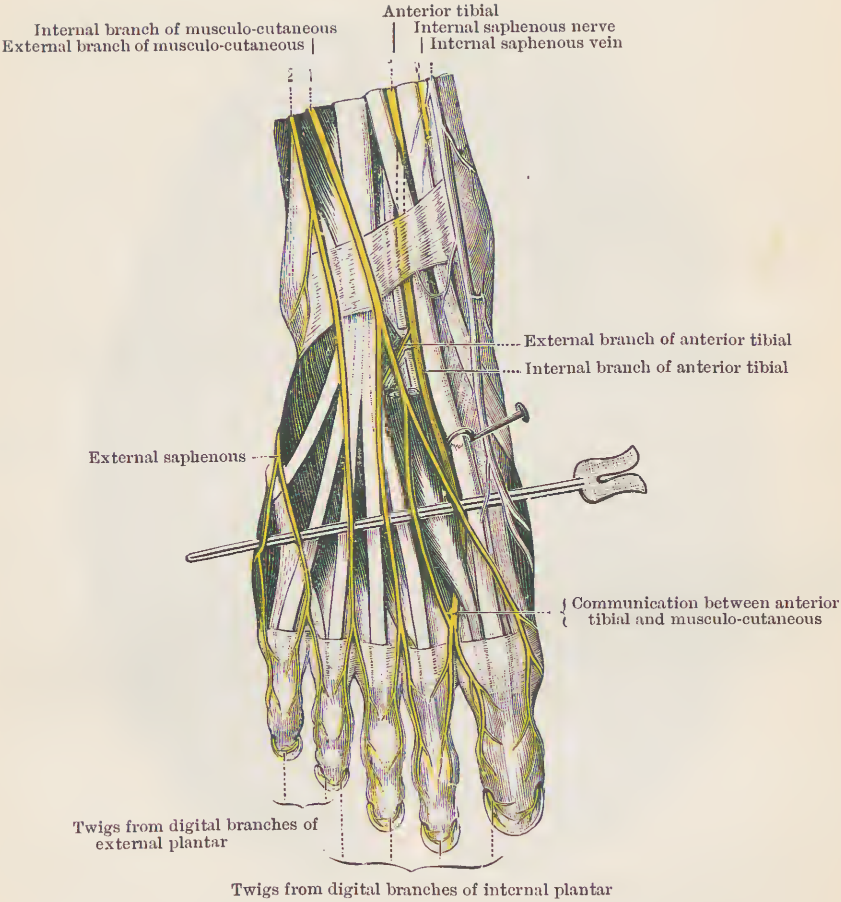

FIG. 400.—NERVES OF THE DORSUM OF THE FOOT. (L. Testut.)

To face p. 536.

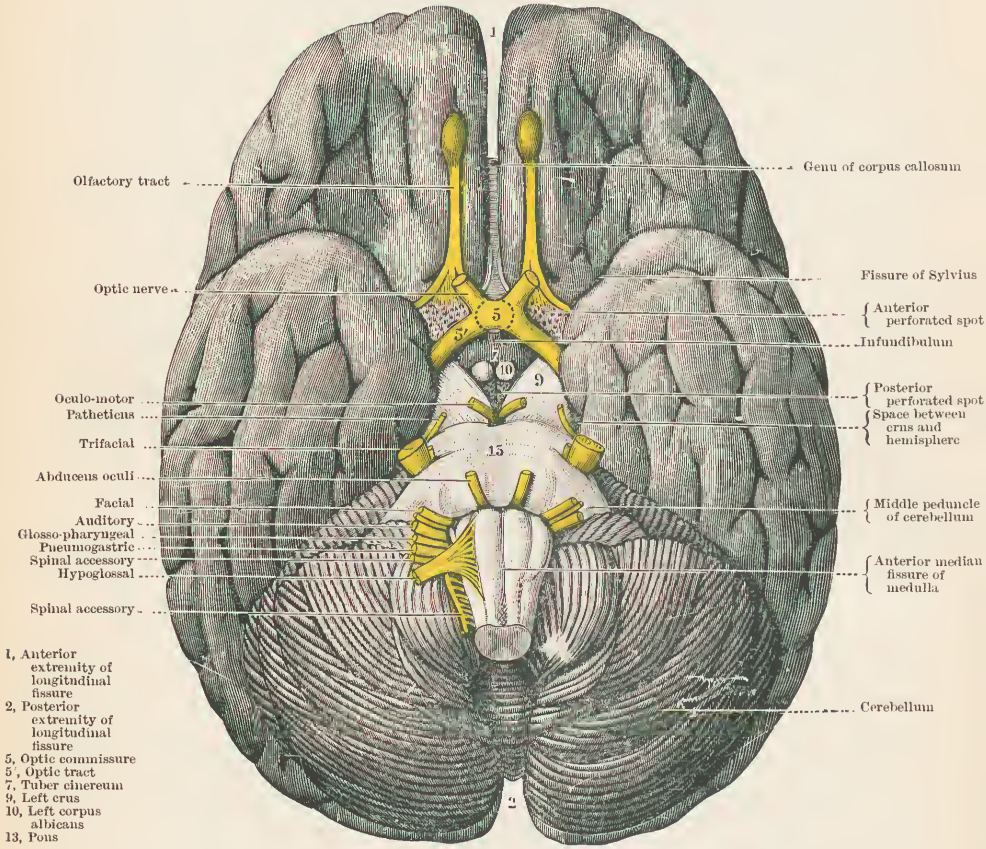

FIG. 401.—THE BASE OF THE BRAIN, showing the origins of the Cranial Nerves. (L. Testut.)

To face p. 537.

THE CRANIAL NERVES.

The cranial nerves are numbered from before backwards, and each is, in addition, distinguished by a special name. According to the system of

Names.[1]		System of Willis.	System of Soemmerring.
Olfactory,	*a*	First.	First.
Optic,	*a*	Second.	Second.
Oculo-motor,	*e*	Third.	Third.
Pathetic or trochlear,	*e*	Fourth.	Fourth.
Trifacial or trigeminal,	*a*, *e*	Fifth.	Fifth.
Abducent ocular,	*e*	Sixth.	Sixth.
Facial,	*e*	Seventh. Portio dura.	Seventh.
Auditory,	*a*	Seventh. Portio mollis.	Eighth.
Glosso-pharyngeal,	*a*, *e*	Eighth.	Ninth.
Pneumogastric or vagus,	*a*, *e*	Eighth.	Tenth.
Spinal accessory,	*e*	Eighth.	Eleventh.
Hypoglossal,	*e*	Ninth.	Twelfth.

[1] In this table *a* stands for afferent, and *e* for efferent.

Soemmerring, which is now usually adopted, twelve pairs are enumerated; in the older system of Willis they were arranged in nine pairs. In comparing the two systems, the first six nerves in each correspond; the seventh nerve of Willis forms the seventh and eighth of Soemmerring. The eighth nerve of Willis corresponds in the more modern system to three trunks, the ninth, tenth, and eleventh; and the ninth nerve of Willis becomes in the classification of Soemmerring the twelfth. In speaking of the nerves behind the sixth, it is advisable to employ the descriptive names of the trunks, as the use of the numbers may lead to confusion.

THE FIRST OR OLFACTORY NERVE.

The first or olfactory nerve (Figs. 407, 408) consists of a brush of filaments arising from the olfactory lobe of the brain. This lobe in many mammals projects forwards from the under surface of the frontal region of the hemisphere and contains in its interior a ventricle, but in man and the ape it is much reduced in size. It is rudimentary in the seal, and absent in the cetacean. In man the lobe presents an olfactory bulb and tract.

The *olfactory nerve-filaments* number from twenty to thirty; they are

non-medullated. They descend through the foramina of the cribriform plate of the ethmoid, receiving, as they pass through the bone, sheaths from the dura mater. They are grouped into an outer and an inner set, and in their distribution are confined to the upper or ethmoidal region of the nasal fossa. The outer set ramifies on the surface of the upper and middle turbinate bones, the inner set is distributed upon the upper part of the septum.

THE SECOND OR OPTIC NERVE.

The optic nerve is, like the olfactory lobe, in reality a portion of the brain. It is continued from the optic commissure or chiasma, and terminates in the retina; from the chiasma two flattened white bands, the optic tracts, are continued backwards, one on each side, and pass round the crura to the region of the corpora quadrigemina and the posterior part of the optic thalamus.

The *optic chiasma* lies immediately in front of the infundibulum, and between the anterior perforated spots, on the under surface of the floor of the third ventricle; inferiorly it rests on the olivary process of the sphenoid bone. It is formed of nerve fibres, the majority of which pass from the retinae. These fibres undergo a partial decussation in the chiasma. The posterior part of the chiasma is formed of very fine fibres, which are not continued into the optic nerves; they constitute the commissures of Gudden and Meynert.

The *optic nerves* pass forwards on each side from the chiasma. Each traverses the optic foramen, lying internal to and above the ophthalmic artery, and is continued within the orbit to the eyeball, which it enters at a spot a little internal to and a little below the middle point of its posterior surface. The nerve is surrounded by a strong sheath from the dura mater, and its fibres are divided into separate bundles by fibrous septa. The central artery of the retina passes into it from below and is continued forwards in its substance.

In the chiasma the nerve fibres which come from the outer or temporal side of each retina pass backwards to the tract of their own side without decussation. The fibres from the nasal or inner side of the retina cross in the chiasma to the opposite tract. Each tract therefore contains the temporal or outer fibres of its own side and the inner or nasal fibres of the opposite side.

The optic nerve and retina of each side are developed as a vesicular outgrowth from the region of the fore brain. The outgrowth is formed of a hollow stalk and a terminal dilatation. By the approximation of the walls of the stalk to one another and their subsequent thickening the optic nerve is formed. Nerve fibres, growing from the retina, pass backwards along the stalk, which becomes solid. The fibres of opposite sides partially decussating, give rise to the chiasma, and, continued backwards, form the greater part of the tracts. In many of the mammalia, and in all vertebrates below mammals, the decussation of the fibres is complete.

THE THIRD OR OCULO-MOTOR NERVE.

The third nerve (Fig. 403) is distributed to all the muscles of the orbit with the exception of the external rectus and the superior oblique, and through its connection with the lenticular ganglion supplies the ciliary muscle and the sphincter of the pupil. The nerve springs by several bundles from the inner side of the crus cerebri, immediately in front of the pons. It passes forwards, crossing below the posterior cerebral artery, and pierces the dura mater between the anterior and posterior clinoid processes. It then runs forwards in the outer wall of the cavernous sinus, and, on gaining the sphenoidal fissure, breaks up into an upper and a lower division; these, passing between the heads of the external rectus muscle, enter the orbit separately, the nasal branch of the ophthalmic division of the fifth intervening between them The **upper division** supplies the levator palpebrae and the superior rectus. The **lower division** furnishes, near the back of the orbit, the short root of the lenticular ganglion, and afterwards divides into three branches distributed respectively to the inferior rectus, the internal rectus, and the inferior oblique. In passing along the wall of the cavernous sinus the third nerve forms communications with the cavernous plexus of the sympathetic, and occasionally with the sixth nerve and the ophthalmic division of the fifth.

The *nucleus of origin* of the third nerve lies immediately ventral to the aqueduct of Sylvius, and extends from the level of the posterior margin of the anterior quadrigeminal body forwards into the region of the hinder part of the third ventricle. The great majority of the root-fibres from the nucleus pass to the nerve of the same side, but a few of the most posterior undergo decussation.

THE FOURTH, THE PATHETIC, OR TROCHLEAR NERVE.

The fourth (Fig. 402), the smallest of the cranial nerves, supplies the superior oblique muscle of the orbit. It springs from the anterior and outer part of the valve of Vieussens, and passes outwards across the superior cerebellar peduncle, and then bends forwards, outwards, and downwards round the outer side of the crus cerebri, between the posterior cerebral and superior cerebellar arteries. It pierces the dura mater at the free edge of the tentorium, immediately behind the posterior clinoid process, and continues its course along the outer wall of the cavernous sinus, between the third nerve and the ophthalmic division of the fifth. In this part of its course it receives a communicating branch from the cavernous plexus of the sympathetic, and from the ophthalmic division of the fifth. Bending upwards and crossing the outer side of the third nerve it reaches the sphenoidal fissure, through which it passes. It enters the orbit above and internal to the other nerves, runs forwards and inwards above the levator palpebrae, and terminates by entering the upper surface of the superior oblique muscle.

The *nucleus of origin* of the fourth nerve is situated in the grey matter of the floor of the aqueduct of Sylvius, at the level of the posterior quadrigeminal body and immediately behind the oculo-motor nucleus. The fibres from the nucleus curve outwards on the surface of the posterior longitudinal bundle, and turning upwards by the inner side of the nucleus of the fifth nerve, enter the anterior medullary velum, or valve of Vieussens, in which they pass across the middle line, decussating with those of the opposite side. The decussation is apparently complete, and the fourth nerve is peculiar in this respect.

THE FIFTH, THE TRIFACIAL, OR TRIGEMINAL NERVE.

The fifth (Figs. 401, 402), much the largest of the cranial nerves, springs in two portions, a sensory and a much smaller motor, from the side of the pons, a little behind the anterior curved border. The sensory fibres pass through a great ganglion (the Gasserian ganglion), and break up into three divisions, the ophthalmic, superior maxillary, and inferior maxillary. The motor portion joins the inferior maxillary division. The nerve has the peculiarity, that branches from all its three divisions furnish roots of small ganglia which have likewise roots from the sympathetic. The ophthalmic division furnishes a root to the ciliary ganglion; the superior maxillary division is connected with the spheno-palatine ganglion; the inferior maxillary gives branches to the otic ganglion, and to the submaxillary ganglion.

Either directly or through its associated ganglia the fifth nerve distributes sensory branches to the eyeball, to the skin of the face and the frontal and temporal regions of the head, to the mucous membrane of the nose, the roof of the mouth, the anterior part of the tongue and the floor of the mouth, and to both upper and lower teeth. The muscular branches supply the muscles of mastication. From the otic ganglion branches pass to the tensor tympani and tensor palati.

The nuclei of origin. From the place of emergence on the side of the pons the fibres may be traced for a little distance in a dorsal direction and slightly backwards; and many of them are found to terminate in two nuclei which lie side by side, ventral to the lateral part of the floor of the anterior portion of the fourth ventricle. These nuclei, of which the outer is sensory, the inner motor, receive, however, only a portion of the fibres; the remainder form two roots, named respectively retroserial and proserial in position. The retroserial root, formed of sensory fibres, descends in the medulla and the upper part of the spinal cord, gradually decreasing in size, as far as the level of the origin of the second or third cervical nerve. The cells among which its fibres terminate may be regarded as continuing the line of the sensory nucleus of the fifth downwards to the substantia gelatinosa of Rolando in the cord. The proserial root, gradually diminishing in size, passes forwards in the isthmus cerebri as far as the level of the anterior quadrigeminal bodies. The cells among which its fibres terminate are situated in the lateral part of the grey

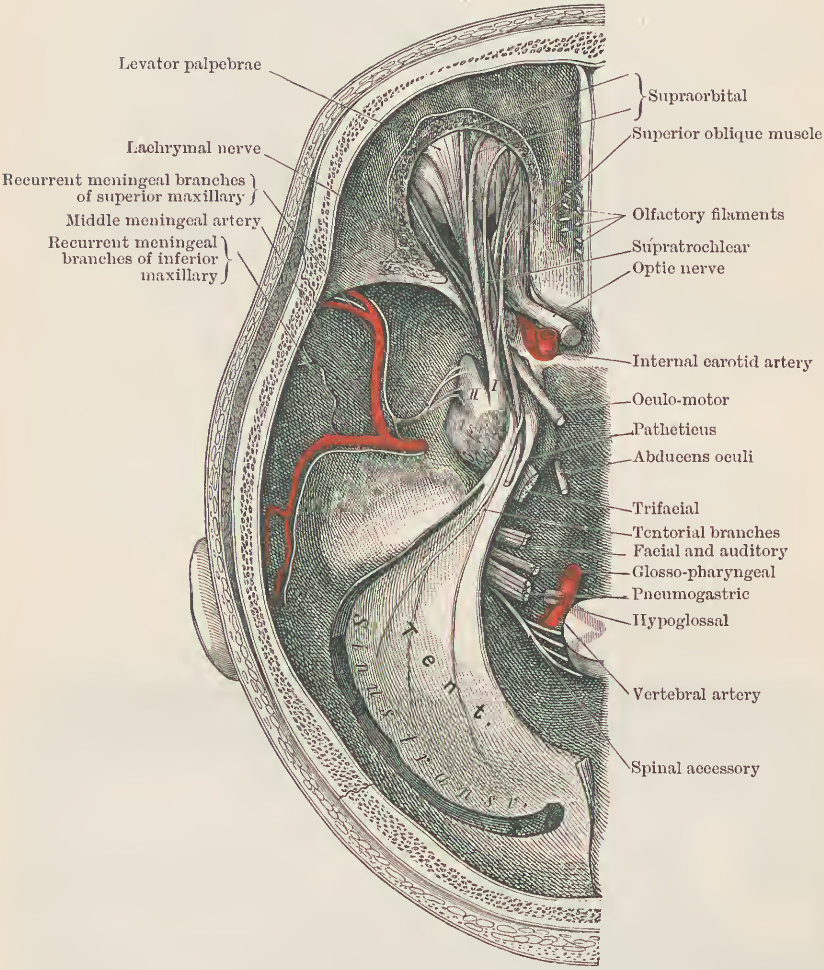

FIG. 402.—THE PLACES OF EXIT FROM THE SKULL OF THE CRANIAL NERVES. (C. Gegenbaur.)

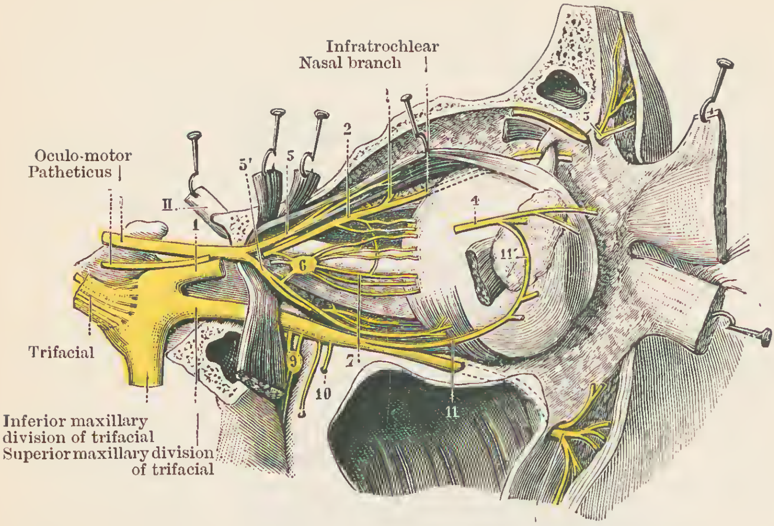

FIG. 403.—THE NERVES OF THE ORBIT. II., Optic nerve: 1, ophthalmic division of trifacial; 2, nasal branch; 3, supratrochlear; 4, lachrymal; 5, upper division of oculo-motor; 5′, lower division of oculo-motor; 6, lenticular ganglion; 7, short ciliary nerves; 9, Meckel's ganglion; 10, posterior superior dental nerves; 11, orbital branch of superior maxillary. (L. Testut.)

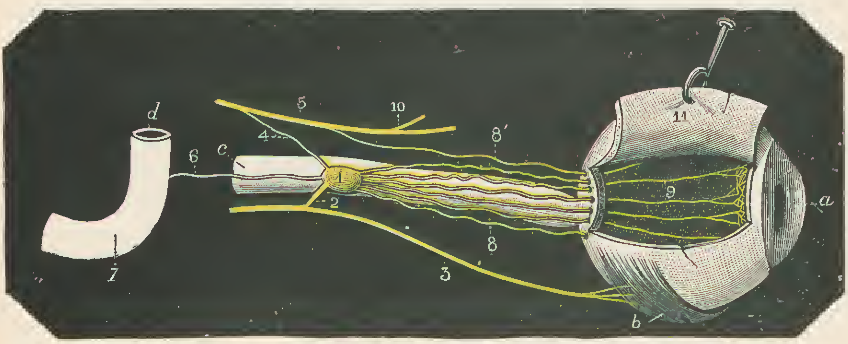

FIG. 404.—THE LENTICULAR OR CILIARY GANGLION from the outer side. *a*, Globe of the right eye; *b*, inferior oblique muscle; *c*, optic nerve; *d*, 7, internal carotid artery: 1, lenticular ganglion; 2, short root; 3, inferior division of oculo-motor; 4, long root; 5, 10, nasal branch of ophthalmic; 6, sympathetic root; 8, short ciliary nerves; 8′, one of the long ciliary nerves; 9, ciliary nerves within the eyeball; 11, sclerotic. (L. Testut.)

matter of the aqueduct. The function of the proserial root is still the subject of controversy; but while many regard it as motor, it seems most probable that it is sensory, and that the two roots are to be compared to the ascending and descending fibres of the posterior root of a spinal nerve.

The trunk of the nerve passes from the side of the pons forwards and outwards, to enter an aperture in the dura mater above and immediately external to the apex of the petrous part of the temporal bone, where the sensory part, becoming expanded and somewhat plexiform, is continued into the ganglion. The *Gasserian ganglion* occupies a recess in the dura mater, and rests on a depression near the apex of the superior surface of the petrous bone. In its longest diameter, from before backwards and outwards, it measures about five-eighths of an inch. It is of a soft texture and reddish colour. Internally it is in contact with the cavernous sinus; anteriorly it rests upon the internal carotid artery, separated from the vessel by the fibrous tissue which crosses the foramen lacerum medium. From its anterior or convex border the three great divisions of the nerve are directed to the sphenoidal fissure, the foramen rotundum, and the foramen ovale. Small branches are described as passing from it to the carotid plexus of the sympathetic and to the dura mater. The *motor portion* (*portio minor*) arises a little in front of but in close proximity to the sensory portion, and passes forwards and outwards beneath it to join in its entirety the inferior maxillary division.

The First Division or Ophthalmic Nerve.

The ophthalmic division, the smallest of the three, passes forwards in the outer wall of the cavernous sinus towards the sphenoidal fissure, lying, in its course, below and to the outer side of the fourth nerve. It detaches a small twig to the dura mater, and is connected with the cavernous plexus of the sympathetic, and with the third, fourth, and sixth nerves. Before reaching the sphenoidal fissure it gives off the nasal branch, and divides into the frontal and lachrymal branches. The nasal nerve enters the orbit between the upper and lower divisions of the third nerve, and passes between the heads of the external rectus muscle. The frontal and lachrymal, keeping to the outer side of the third nerve, enter the orbit above the upper head of the external rectus muscle.

The **frontal nerve**, the largest of the three, runs forwards above the levator palpebrae muscle, and about the middle of the orbit divides into the supraorbital and supratrochlear branches. The *supraorbital nerve*, the main continuation of the frontal, emerges along with the supraorbital artery by the supraorbital notch, detaches filaments to the skin and conjunctiva of the upper eyelid, and divides into two branches which ramify in the integument of the front of the head, the outer and larger reaching backwards beyond the vertex. The *supratrochlear nerve*, much smaller than the supraorbital, emerges above the

pulley of the superior oblique muscle; it is connected with the infratrochlear nerve, detaches filaments to the upper eyelid, and ramifies with the frontal artery over the root of the nose and the anterior part of the forehead.

The **lachrymal nerve** (Fig. 402) passes forwards along the angle between the roof and the outer wall of the orbit, in company with the lachrymal branch of the artery. It detaches a slender twig which joins the temporal branch of the temporo-malar nerve, and terminates in filaments which are distributed to the lachrymal gland, to the integument at the outer canthus, and to the skin and conjunctiva of the outer part of the upper eyelid.

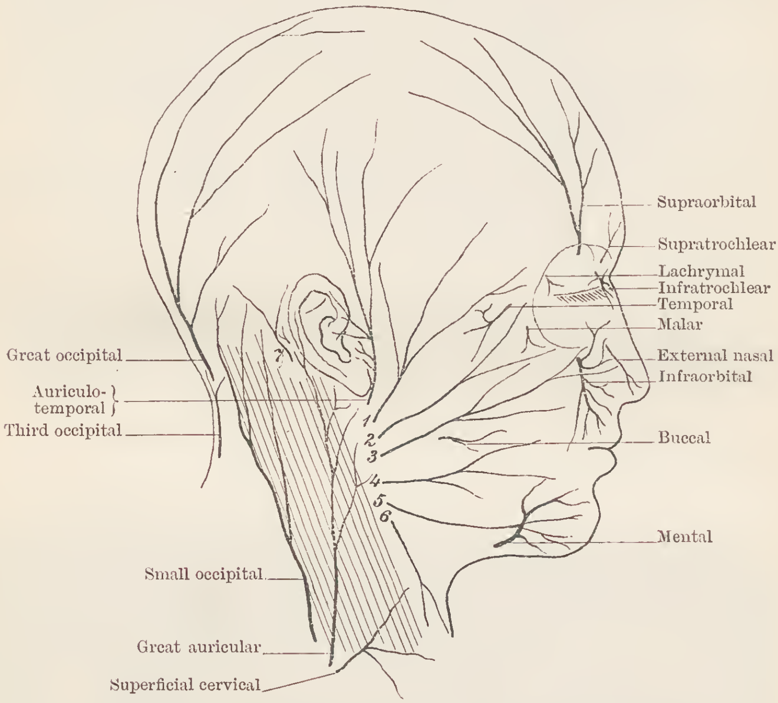

FIG. 405.—DIAGRAM OF THE NERVES OF THE FACE AND SCALP. 1 to 7, Branches of facial nerve: 1, temporal; 2, malar; 3, infraorbital; 4, buccal; 5, supramaxillary; 6, inframaxillary; 7, posterior auricular. Immediately above the posterior auricular the auricular branch of the pneumogastric is figured. (J. Y. M.)

The **nasal nerve** (Figs. 403, 407, 408), entering the orbit between the heads of the external rectus muscle, passes forwards and inwards over the optic nerve. It then enters the anterior internal orbital foramen, and along with the anterior ethmoidal artery crosses the upper surface of the horizontal plate of the ethmoid bone, lying immediately underneath the dura mater of the anterior cranial fossa. Through the aperture by the side of the crista galli it descends into the nose, where it at once breaks up into an outer and an inner terminal division. As it is entering the orbit it detaches *the long root of the lenticular ganglion*, a slender twig which reaches the posterior and upper

angle of the ganglion. Crossing the optic nerve the nasal detaches *the long ciliary nerves*, two in number, which run forward by the inner side of the optic nerve, and pierce the back of the sclerotic coat of the eyeball along with the short ciliary nerves from the ganglion. Before leaving the orbit it gives off the *infratrochlear branch*, a slender twig which, passing forwards, emerges below the pulley of the superior oblique muscle, sends upwards a connecting filament to the supratrochlear nerve, and terminates in branches which ramify in the skin and conjunctiva at the inner canthus. The *inner terminal branch* of the nasal nerve ramifies on the anterior and upper part of the septum of the nose. The *outer terminal branch* descends on the deep surface of the nasal bone, furnishing filaments which ramify in front of the upper and middle turbinate processes; it then emerges between the lower edge of the nasal bone and the upper lateral cartilage, and descends on the deep surface of the compressor naris to the point of the nose, supplying the integument of the bridge.

The **lenticular or ciliary ganglion** (Fig. 404) is usually described along with the fifth nerve, although it is probable from its development that it is to be regarded as more closely related to the oculo-motor trunk. It is a small four-sided body of a reddish colour, and measures from before backwards about a twelfth of an inch; it is to be found in the posterior part of the orbit, and lies on the outer side of the optic nerve. It receives posteriorly three roots: *the long root*, sensory, comes from the nasal branch of the ophthalmic and joins the upper and posterior angle of the ganglion; *the short root*, motor, from the lower division of the third, joins the lower and posterior angle; *the middle root*, from the cavernous plexus of the sympathetic, very slender, either reaches the ganglion between the other two or is incorporated for a longer or shorter distance with one or other. From the anterior extremity of the ganglion *the short ciliary nerves* are given off; they are at first six or eight in number, but dividing they form from fifteen to twenty filaments which, encircling the optic nerve, and forming two groups, an upper and a lower, reach the back of the eyeball. The long ciliary nerves from the nasal nerve form connections with and accompany the branches of the ganglion. The ciliary nerves pierce the sclerotic in a ring round the entrance of the optic nerve. They distribute sensory filaments to the eyeball from the fifth nerve, motor fibres to the ciliary muscle and sphincter of the pupil from the third nerve, and, from the cavernous plexus of the sympathetic, fibres which, on stimulation, produce dilatation of the pupil.

The Second Division or Superior Maxillary Nerve.

The superior maxillary nerve (Fig. 406), directed forwards and a little outwards, emerges from the cranium by the foramen rotundum, crosses the upper part of the spheno-maxillary fossa, passes along the infraorbital groove and canal, and appears on the face at the infraorbital foramen, on emerging from which it breaks up, on the deep surface of the levator labii superioris

muscle, into its terminal branches. Within the cranium it detaches some small recurrent meningeal branches. Crossing the spheno-maxillary fossa it gives off from its upper margin an orbital branch, and, from below, the two spheno-palatine branches to Meckel's ganglion. As it passes forwards upon the superior maxillary bone it detaches the posterior, middle and anterior superior dental nerves. The terminal part, sometimes named the infraorbital nerve, breaks up into inferior palpebral, lateral nasal, and superior labial branches, which form with the branches of the facial nerve free communications to which the name infraorbital plexus has been given.

The **orbital** or **temporo-malar branch** (Fig. 403) enters the orbit by the spheno-maxillary fissure and divides into two slender nerves, the temporal and malar branches. The *temporal branch* ascends on the outer wall, is connected by one or two slender filaments with the lachrymal nerve, and pierces the bone at the level of the outer canthus; it is then directed outwards and backwards over the anterior part of the temporal muscle, and pierces the temporal fascia about an inch above the zygoma and a little behind the malar bone; it is connected with the facial nerve, and supplies the skin of the anterior part of the temporal region. The *malar branch* is directed forwards to the malar foramen, through which it passes, to appear upon the surface at the most prominent part of the cheek; it is connected with the facial nerve and ramifies in the skin covering the malar bone.

The **spheno-palatine nerves** are two short stems which descend to the anterior part of the spheno-palatine ganglion; some of their fibres terminate in the ganglion, of which they form the sensory roots; many, however, are prolonged beyond the ganglion into its palatine and nasal branches.

The **superior dental nerves** supply the teeth of the upper jaw, and detach filaments to the mucous membrane of the outer side of the gum and the adjacent area, and the lining membrane of the antrum of Highmore. They communicate with one another in a plexus within the substance of the alveolar ridge. The *posterior nerve* arises either as one branch which rapidly subdivides or as two separate branches from the main trunk as it is entering the infraorbital groove; the branches descend upon the posterior surface of the superior maxillary bone and enter bony canals, within which they break up into twigs which supply the molar teeth. The *middle nerve*, often absent altogether, arises in the infraorbital groove, is directed forwards and inwards, and descends in a special canal in the outer wall of the antrum; it supplies the bicuspid teeth. The *anterior nerve* arises in the infraorbital canal and descends in the anterior wall of the antrum; it detaches a filament to the mucous membrane of the anterior part of the inferior turbinate bone and the lower meatus of the nose, and breaks up into branches which supply the incisor, canine, and, in the absence of the middle nerve, the bicuspid teeth.

The infraorbital or terminal branches. The *inferior palpebral branches*, usually two in number, are the smallest of the terminal offsets; they are

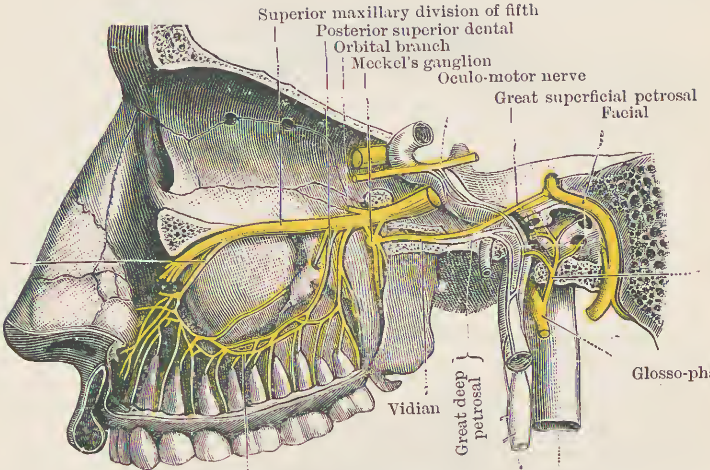

Fig. 406.—The Superior Maxillary Division of the Fifth Nerve. (L. Testut.)

To face p 544.

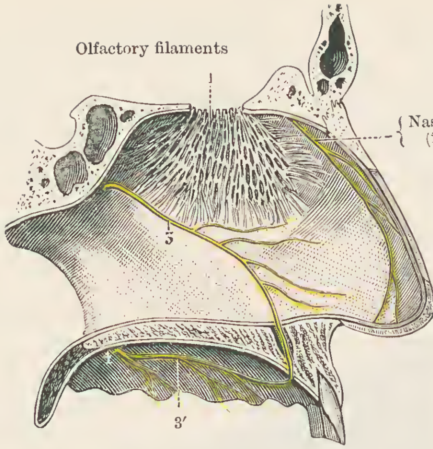

FIG. 407.—NERVES OF THE NASAL SEPTUM. (L. Testut.)

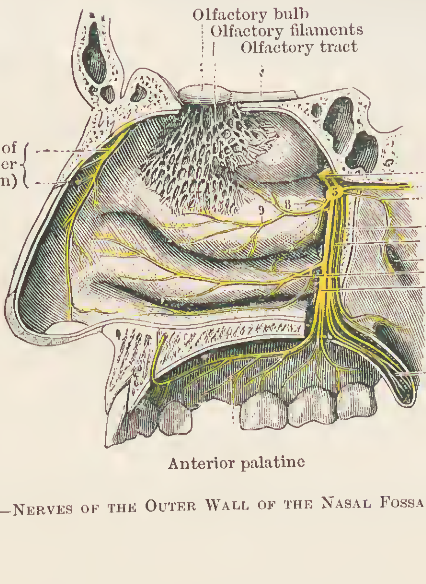

FIG. 408.—NERVES OF THE OUTER WALL OF THE NASAL FOSSA. (L. Testut.

To face p. 545.

directed upwards and supply the skin and conjunctiva of the lower lid. The *lateral nasal branches*, three or four in number, supply the integument of the side of the nose. The *superior labial branches*, usually four in number, descend to ramify in the skin and mucous membrane of the upper lip.

The **spheno-palatine ganglion (Meckel's ganglion)** (Figs. 406, 408), lies in the spheno-maxillary fossa; it is triangular in outline, and measures from before backwards, its longest diameter, about a fifth of an inch. Its *sensory root* comes from the superior maxillary of the fifth and is formed by the two spheno-palatine nerves already described. The motor and sympathetic roots are conjoined for some distance, and form the Vidian nerve which enters the ganglion from behind. The *motor root*, the *great superficial petrosal nerve*, takes origin from the geniculate ganglion of the facial nerve; it is directed forwards in the hiatus Fallopii, and is joined on the outer side of the internal carotid artery, in the foramen lacerum medium, by the *sympathetic root*, the *great deep petrosal nerve*, which is derived from the carotid plexus of the sympathetic. The *Vidian nerve*, thus formed, passes forwards in the Vidian canal to the posterior angle of the ganglion. It detaches one or two small branches which pierce the floor of the canal and ramify in the lining membrane of the upper and posterior part of the nasal fossa; their fibres probably run backwards in the trunk of the Vidian from the ganglion. The branches of the ganglion are superior, posterior, internal, and inferior.

The *orbital* or superior branches, two or three slender twigs, enter the orbit, pierce its inner wall, and ramify in the lining membrane of the posterior ethmoidal cells.

The *pharyngeal* or posterior branch, a very slender twig, courses in the pterygo-palatine canal, detaches some twigs to the lining membrane of the sphenoidal sinus, and is distributed to the mucous membrane of the upper part of the pharynx in the neighbourhood of the Eustachian tube.

The *nasal* branches, partly prolonged directly from the spheno-palatine roots, are directed inwards through the spheno-palatine foramen; they are eight or nine in number, and are mostly of small size. They ramify upon the roof, the posterior and lower part of the septum, and the lateral wall of the nose, extending as far down as the middle meatus. One of them, much larger than the others, the *naso-palatine nerve* (nerve of Cotunnius), descends upon the septum and enters the palate through the anterior palatine fossa, to terminate in branches which supply the mucous membrane of the anterior region of the hard palate and gum, and form communications with those of the great palatine nerve. The left naso-palatine branch descends through the anterior of the foramina of Scarpa, while the right occupies the posterior, and communications pass between the two nerves.

The *palatine branches*, three in number, descend in the palato-maxillary canal; like the nasal branches, they are partly prolonged directly from the spheno-palatine roots. They are named respectively from the bony apertures

from which they emerge—the large or anterior, the small or posterior, and the smallest or external. The *large palatine nerve* (palato-nasal) detaches, as it descends, two branches which ramify on the posterior part of the lateral wall of the nose in the region of the middle and lower meatus. Afterwards, it bends forwards on the under surface of the hard palate, and breaks up into branches which supply the mucous membrane of the hard palate and gum in nearly the whole extent, and communicate with the branches of the naso-palatine nerve. The *small palatine nerve* ramifies in the mucous membrane of the soft palate. By many it is regarded as giving to the levator palati and azygos uvulae muscles branches of supply, the fibres of which are supposed to be derived from the facial through the great superficial petrosal nerve; others hold that these muscles are supplied by the spinal accessory nerve through the pharyngeal plexus. The *smallest palatine nerve* is directed outwards and downwards, and ramifies over the outer part of the soft palate and the tonsil.

The Third Division or Inferior Maxillary Nerve.

The inferior maxillary nerve (Figs. 409, 410), the largest of the three divisions, escapes from the skull by the foramen ovale, and enters the zygomatic fossa; it is formed of two roots which join with one another immediately beyond the foramen; the larger of the two is sensory, and comes from the Gasserian ganglion; the smaller is the motor root of the fifth. The trunk thus formed is very short, and lies on the deep aspect of the external pterygoid muscle. It detaches a recurrent branch and the nerve to the internal pterygoid muscle, and immediately afterwards breaks up into an anterior and a posterior portion, which, close to their origin, are frequently separated from one another by a ligamentous band or bony spicule stretched from the external pterygoid plate to the great wing of the sphenoid bone in the neighbourhood of the spine. The *recurrent branch* (Fig. 402) passes upwards through the foramen spinosum and divides into two slender twigs, one of which ramifies in the dura mater, while the other, passing through the petro-squamous fissure, ramifies in the lining membrane of the mastoid cells. The **nerve to the internal pterygoid** springs from the deep surface of the parent trunk, and passes downwards under the cover of the pterygo-spinous ligament to reach the deep surface of the internal pterygoid muscle. Near its origin it is connected with the otic ganglion.

The *anterior portion*, chiefly motor in function, immediately breaks up into the masseteric, buccal, external pterygoid, and deep temporal branches. The **masseteric nerve**, a considerable branch, passes upwards under cover of the upper head of the external pterygoid muscle, detaches a posterior deep temporal twig, and bends outwards in the sigmoid notch to enter the deep surface of the masseter muscle. The **buccal nerve** (long buccal) is directed outwards between the heads of the

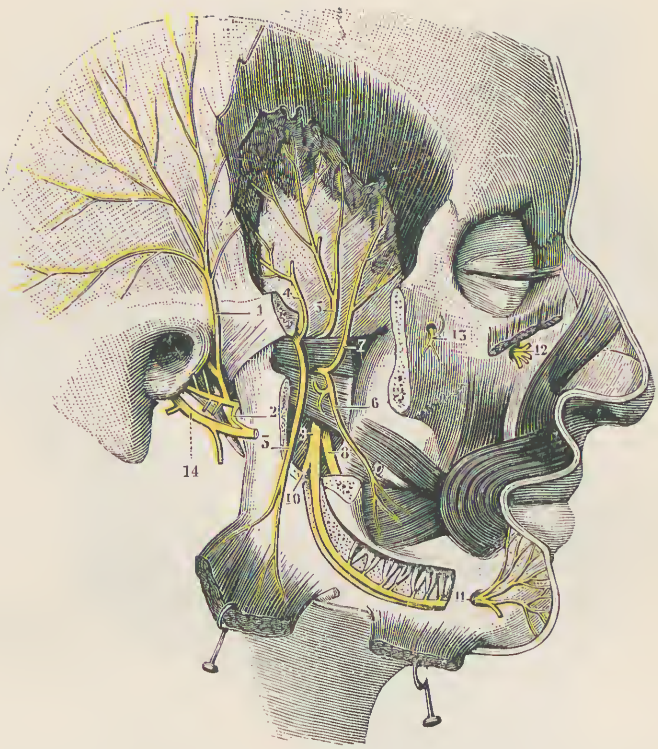

FIG. 409.—BRANCHES OF THE INFERIOR MAXILLARY DIVISION OF THE FIFTH NERVE. 1, Auriculo-temporal; 2, connecting branch with facial; 3, masseteric; 4, posterior deep temporal; 5, middle deep temporal; 6, buccal; 7, anterior deep temporal; 8, lingual; 9, inferior dental; 10, branch to mylo-hyoid and anterior belly of digastric; 11, mental; 12, infraorbital branches of superior maxillary; 13, malar branch of superior maxillary; 14, facial nerve. (L. Testut.)

To face p. 546.

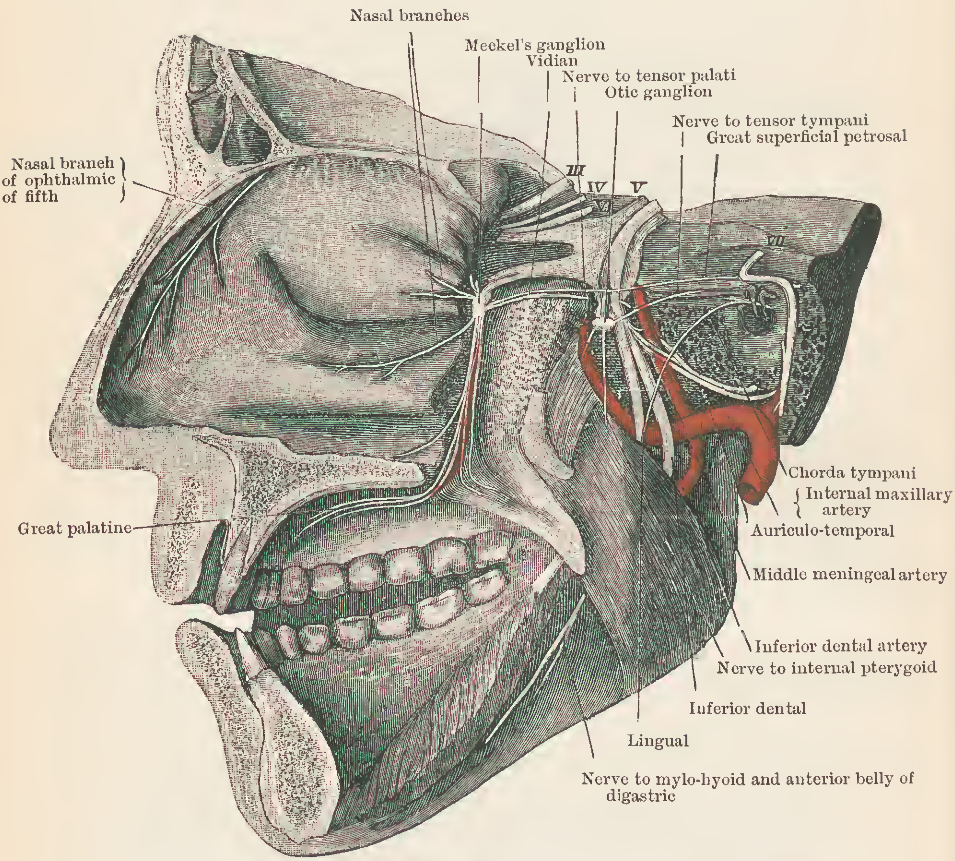

FIG 410.—THE SPHENO-PALATINE AND OTIC GANGLIA FROM THE DEEP SURFACE. (C. Gegenbaur.)

To face p. 547.

external pterygoid muscle, and then bends forwards on the deep surface of the insertion of the temporal muscle, which it sometimes pierces. Escaping from under cover of the ramus it ramifies in the fat of the cheek, forming communications with the facial nerve; its terminal branches, which are sensory, supply the mucous membrane of the cheek, and the skin at the angle of the mouth. Near its origin it detaches the external pterygoid nerve and the anterior deep temporal nerve. The **external pterygoid nerve** arises with the buccal branch and enters the deep surface of the external pterygoid muscle. The **deep temporal nerves** are commonly three in number. The anterior usually springs from the buccal nerve, and ascends on the outer surface of the upper head of the external pterygoid muscle; the middle springs directly from the parent trunk and ascends on the deep surface of the external pterygoid muscle; the posterior arises in common with the masseteric branch. They all enter the temporal muscle from its deep surface.

The *posterior portion*, which is chiefly sensory, breaks up into three important trunks—the auriculo-temporal, the inferior dental, and the lingual.

The **auriculo-temporal nerve** (Fig. 409) arises by two roots which pass backwards and join with one another, embracing between them the middle meningeal artery; the nerve then bends upwards on the deep surface of the temporo-maxillary articulation, passes through the parotid gland, and crosses the zygoma, lying behind the temporal artery and on its deep surface. Continuing its course it ascends in front of the ear and breaks up into long slender terminal branches. Near its origin it detaches (*a*) *communicating twigs to the otic ganglion*, (*b*) *two communicating branches to the temporo-maxillary division of the facial nerve*, (*c*) some *branches to the parotid gland*, and (*d*) a *nerve to the temporo-maxillary articulation*. As it is crossing the zygoma it detaches (*e*) *two nerves to the meatus*; these branches, very slender and lying close to the bone, enter the external auditory canal, and are distributed to the integument lining it, the upper of the two furnishing a branch to the tympanic membrane. As the nerve passes in front of the external ear (*f*) *two auricular branches* are given off; these nerves supply the skin of the tragus and the anterior part of the helix. The *terminal* or *temporal branches* ascend with the branches of the temporal artery superficial to which they lie; they supply the integument of the region above and in front of the ear, and form communications with branches of the facial nerve.

The **inferior dental nerve** (Fig. 409) is the largest branch of the inferior maxillary trunk; it is not entirely sensory as it detaches a muscular twig to the mylo-hyoid and the anterior belly of the digastric. It passes downwards and outwards behind the lingual nerve to reach the inferior dental canal, descending at first under cover of the external pterygoid muscle, and afterwards resting upon the internal pterygoid, on the deep surface of the ramus. Within the canal it is continued forwards almost to the middle line, detaching branches which, after communicating with one another and furnishing

filaments to the gums, supply the teeth of the lower jaw. The *mylo-hyoid nerve* is given off by the main trunk before it enters the inferior dental canal; it runs forwards on the under surface of the mylo-hyoid, supplying twigs to it, and terminates in the anterior belly of the digastric. The *mental branch*, of considerable size, leaves the main trunk as it is passing forwards in the canal; it escapes by the mental foramen, and breaks up into branches which supply the integument of the chin and the skin and mucous membrane of the lower lip, and form connections with branches of the facial nerve. The mental branch is larger than the terminal part of the main trunk, which latter sometimes receives the name of incisor branch.

The **lingual** or **gustatory nerve** (Figs. 411, 413) descends in front of the inferior dental nerve, to which a bundle of its fibres may for a short distance adhere. On the deep surface of the external pterygoid muscle it is, near its origin, joined from behind by the chorda tympani nerve from the facial. On emerging from the cover of the external pterygoid it passes between the internal pterygoid and the ramus, and, crossing the anterior border of the superior constrictor of the pharynx, reaches the floor of the mouth immediately below the last molar tooth of the lower jaw. Continuing its course, it runs forwards on the hyo-glossus, forming a bend with the convexity downwards, passes under cover of the mylo-hyoid muscle, and, crossing Wharton's duct, gains the margin of the under surface of the tongue, along which it is continued to the tip. Near the posterior border of the mylo-hyoid it detaches one or two *branches to the submaxillary* ganglion, and gives off the *sublingual branch* which supplies the sublingual gland and furnishes filaments to the gums and to the floor of the mouth. The branches to the ganglion may easily be dissected back to the chorda tympani. A little further forwards the lingual receives a *branch from the ganglion* and two or three *connecting filaments from the hypoglossal nerve.* Its terminal branches are distributed to the gums, to the floor of the mouth, and to the surface of the tongue in the region in front of the circumvallate papillae. The lingual is the nerve of tactile sensibility and of taste of the anterior two-thirds of the tongue; the fibres which subserve the sense of taste are supposed by some to come through the chorda tympani, and to be ultimately derived not from the facial but from the glosso-pharyngeal through its connecting branches with the seventh nerve.

The **submaxillary ganglion** (Fig. 413) is about an eighth of an inch in length. It rests upon the hyo-glossus muscle, immediately below the lingual nerve, near the posterior border of the mylo-hyoid muscle. It receives from the lingual nerve one or two roots, and it also receives a sympathetic root from the plexus on the facial artery. It detaches a number of branches to the submaxillary gland and to Wharton's duct, and one which, joining the trunk of the lingual, passes to the tongue.

The **otic ganglion** (Fig. 410) measures about a fifth of an inch from

before backwards. It is placed immediately below the foramen ovale and in front of the middle meningeal artery. It lies on the deep surface of the inferior maxillary trunk, at the place of origin of the nerve to the internal pterygoid, with which it is usually very closely connected. It receives root fibres from the following sources—(*a*) from the nerve to the internal pterygoid; (*b*) from the small superficial petrosal nerve, which comes from the tympanic branch of the glosso-pharyngeal and receives a communicating filament from the geniculate ganglion of the facial, and afterwards pierces the spheno-petrous suture to reach the ganglion from behind; and (*c*) from the sympathetic on the middle meningeal artery. It is also connected by delicate filaments with the *auriculo-temporal* and *chorda tympani nerves.* It detaches *muscular branches* to the tensor tympani and tensor palati muscles.

Surgical anatomy of the fifth nerve. The branches of the fifth trunk are frequently the seat of severe and obstinate neuralgia, for the relief of which the surgeon is often compelled to excise portions of the nerve. In very severe cases, in which the pain has been referred to all or a considerable proportion of the branches, the Gasserian ganglion itself has been the subject of operation. To reach the ganglion, the zygoma and the coronoid process are divided, the external pterygoid muscle is cut through, and the portion of bone immediately surrounding the foramen ovale is removed; the ganglion is then pulled outwards, and as far as possible removed. This operation is a very serious one. The supraorbital branch of the ophthalmic division is easily exposed by a transverse incision immediately above the supraorbital notch. The infraorbital nerve is also easily reached as it appears upon the face. A great part of the trunk of the superior maxillary division, and Meckel's ganglion, may be removed by first opening the antrum of Highmore through its anterior wall, then perforating the posterior wall of the space, and finally with great care breaking through the thin plate of bone which forms the floor of the infraorbital canal and groove. Exposed in this manner the nerve may be cut through almost as far back as the foramen rotundum. This operation has been practised for the relief of obstinate neuralgia affecting the teeth of the upper jaw. The trunk of the inferior maxillary division has been reached, as it escapes from the skull, by an operation similar to the first stages of that for the removal of the Gasserian ganglion. The inferior dental branch can be exposed from the inside of the mouth, the guide to the nerve being the prominent margin of the inferior dental foramen, which may be felt through the mucous membrane. The lingual nerve can also be reached from the inside of the mouth through an incision made about half an inch below the last molar tooth of the lower jaw.

THE SIXTH, THE ABDUCENT OCULAR NERVE.

The sixth nerve supplies the external rectus muscle. It emerges from the brain at the inferior border of the pons, above and toward the

outer edge of the anterior pyramid. It is directed forwards and pierces the dura mater immediately internal to the apex of the petrous bone, after which it runs through the cavernous sinus below and by the inner side of the ophthalmic division of the fifth nerve. It enters the orbit by the sphenoidal fissure, passing between the heads of the external rectus muscle, and lying below the lower division of the third nerve. About half-way forwards in the orbit it pierces the inner surface of the external rectus. On its way it receives communicating fibres from the carotid plexus and from the ophthalmic division of the fifth nerve.

The *nucleus of origin* lies close to the surface of the floor of the fourth ventricle, near the middle line, and above the striae acusticae.

THE SEVENTH OR FACIAL NERVE.

The facial nerve (Fig. 410) takes origin from the surface of the brain in two portions: the larger portion, the *portio dura*, arises from the side of the medulla, between the olivary and restiform bodies, immediately below the pons; the smaller portion, the *pars intermedia*, takes origin immediately external to the portio dura, between it and the auditory nerve.

The *nucleus of origin* of the portio dura lies in the reticular formation some distance below the surface of the fourth ventricle, about the level of the striae acusticae. The fibres which pass from the nucleus have a tortuous course within the substance of the brain, before they reach the surface; they take first of all a dorsal direction, and approach the floor of the fourth ventricle; they are then continued forwards, running in the eminentia teres; finally, bending at a right angle, they arch outwards over the nucleus of the sixth nerve, and are continued downwards and outwards to the surface. The fibres of the pars intermedia arise from the upper end of the glosso-pharyngeal nucleus.

From its superficial origin the facial nerve passes outwards to the internal auditory meatus, resting in its course upon the upper and anterior surface of the auditory nerve. At the bottom of the meatus it separates from the companion trunk and enters the aqueduct of Fallopius, within which it passes through the temporal bone. Within the aqueduct it first passes outwards above and between the cochlea and vestibule as far as the hiatus Fallopii; it then bends sharply backwards in the substance of the inner wall of the tympanum, above the fenestra ovalis; it finally descends, with a slight arch backwards, behind the tympanic cavity to the stylo-mastoid foramen. The bend which the nerve makes above the fenestra ovalis is known as the "genu," and at its anterior border is a small reddish coloured triangular swelling, the apex of which is directed forwards, the *geniculate ganglion.* The pars intermedia, which from the first is closely applied to the under surface of the portio dura, partly becomes incorporated with the portio dura in the internal auditory meatus, and partly terminates in the ganglion. Below the stylo-mastoid foramen the facial nerve is directed

downwards, outwards, and forwards, and enters the parotid gland, within which it divides into two terminal branches, the temporo-facial and the cervico-facial.

Within the aqueduct of Fallopius a number of branches are detached. (1) The **great superficial petrosal** arises from the apex of the geniculate ganglion, passes forwards in the hiatus Fallopii, crosses below the Gasserian ganglion, and, on the outer side of the internal carotid artery, joins with the great deep petrosal from the carotid plexus of the sympathetic to form the Vidian nerve, which passes to Meckel's ganglion. (2) A **communicating branch** passes from the ganglion *to the small superficial petrosal* which, continued from the tympanic branch of the glosso-pharyngeal, pierces the petrous bone a little external to the hiatus Fallopii, and descends, usually through the spheno-petrous suture, to the otic ganglion. (3) The **nerve to the stapedius muscle**, a small branch, arises as the main trunk descends behind the tympanum. (4) The **chorda tympani**, a branch of some size, arises near the lower end of the aqueduct; it is directed at first upwards and forwards, then pierces the posterior wall of the tympanum, and courses forwards on the inner surface of the tympanic membrane near its upper margin, passing between the long process of the incus and the handle of the malleus. It leaves the tympanum by the canal of Huguier at the inner part of the fissure of Glaser and, after forming connections with the otic ganglion. joins the lingual nerve with which it is distributed to the submaxillary and sublingual glands, and to the anterior two-thirds of the tongue. (5) Occasionally a small branch, the *external superficial petrosal*, passes from the geniculate ganglion to the sympathetic on the middle meningeal artery above the foramen spinosum; and (6) there is frequently a *communicating branch* given off from below the ganglion *to the auricular branch of the pneumogastric.*

Immediately below the stylo-mastoid foramen the facial nerve detaches two branches: (1) The **auricular branch** runs upwards in the fissure between the vaginal and mastoid processes, passes under cover of the retrahens auram, and breaks up into branches which supply the retrahens auram, the small muscles on the inner surface of the auricle, and the occipitalis; it forms connections with branches of the great auricular and small occipital nerves and with the auricular branch of the pneumogastric; (2) **the nerve to the stylo-hyoid and the posterior belly of the digastric** divides and gives a branch to each of these muscles. A *communicating filament from the glosso-pharyngeal nerve* joins the nerve to the stylo-hyoid, or passes directly to the facial in the neighbourhood of the stylo-mastoid foramen.

The terminal branches of the facial are the temporo-facial and cervico-facial. In passing through the parotid gland these nerves cross superficially the external carotid artery and the temporo-maxillary vein; the temporo-facial is connected by two communicating branches with the auriculo-temporal nerve; the cervico-facial forms connections with the branches of the great auricular nerve. Before leaving the gland each of the two

divisions breaks up into three branches. The branches pass forwards over the face and upper part of the neck, ramifying and forming, by their repeated connections with one another, a plexus to which the name "pes anserinus" has been given; they likewise form communications with the various branches of the fifth nerve which appear upon the face.

The **temporo-facial branches** are the temporal, malar, and infraorbital. The *temporal branches* cross the zygoma a little in front of the temporal artery, and pass chiefly towards the upper margin of the orbit. They supply the atollens and attrahens auram, the small muscles of the outer surface of the auricle, the orbicularis palpebrarum, the corrugator supercilii, and the frontalis, and they form connections with the auriculo-temporal, temporal, and supraorbital branches of the fifth. The *malar branches* pass towards the outer angle of the orbit, supply the orbicularis palpebrarum, and form connections with the malar, lachrymal, and infraorbital branches of the fifth nerve. The *infraorbital branches* run forwards above Stenson's duct; they are the largest of the series, and supply the orbicularis palpebrarum, the muscles of the nose, the elevators of the upper lip, the orbicularis oris, and the buccinator; they form connections with terminal twigs of the infraorbital and nasal branches of the fifth.

The **cervico-facial branches** are the buccal, supramaxillary, and inframaxillary. The *buccal branches* run towards the angle of the mouth, supply the buccinator and orbicularis oris, and form connections with the buccal branch of the fifth (long buccal). The *supramaxillary branches* run towards the chin; they supply the orbicularis oris, the muscles of the lower lip, and the levator menti, and form connections with the mental nerve. The *inframaxillary branches* pass out from the lower border of the parotid gland, and ramify under the upper part of the platysma, which they supply; they form connections with the great auricular and superficial cervical nerves.

THE EIGHTH OR AUDITORY NERVE.

The eighth nerve (the portio mollis of the seventh pair of Willis) arises from the side of the medulla oblongata close to the hinder border of the pons, immediately external (dorsal) to the place of origin of the seventh nerve. It passes outwards behind and below the facial nerve, and in close contact with it, and at the bottom of the internal auditory meatus divides into two terminal branches; these, the vestibular and cochlear nerves respectively, are described along with the organ of hearing.

Nuclei of origin. Traced into the medulla, the fibres form two bundles, the *lateral* and *mesial roots*, which embrace the restiform body. The lateral root is mainly continuous with the cochlear, and the mesial with the vestibular nerve. The fibres end in three separate collections of nerve cells. The *ventral nucleus* is a collection of nerve cells which lies in the medulla in the angle between the two roots, and extends in a dorsal

direction in the substance of the lateral root; this nucleus receives the fibres of the lateral or cochlear root. The *dorsal nucleus*, sometimes called the chief nucleus, is a collection of nerve cells placed beneath the floor of the fourth ventricle; it is broadest at its middle part which lies beneath the striae acusticae, and there it reaches inwards to the median line; it extends upwards as far as the level of the nucleus of the sixth nerve. The *nucleus of Deiters* lies by the outer side of the dorsal nucleus and by the inner side of the restiform body; it hardly reaches so far downwards as the dorsal nucleus, and is broadest at its upper end. The fibres of the mesial or vestibular root have been traced to the vicinity of the dorsal nucleus and the nucleus of Deiters.

THE NINTH OR GLOSSO-PHARYNGEAL NERVE.

The glosso-pharyngeal nerve (Figs. 411, 413) is formed from the two anterior of a series of fasciculi which spring separately from the side of the medulla in the line between the olivary and restiform bodies; the two bundles pass outwards and unite with one another to form the trunk of the nerve. The nerve contains both afferent and efferent fibres.

Nuclei of origin. The afferent fibres partly terminate in the anterior or cerebral extremity of the nucleus of the ala cinerea, and partly pass into the funiculus solitarius. The *nucleus of the ala cinerea* is placed beneath the floor of the lower part of the fourth ventricle in the region of the inferior fovea and ala cinerea; at its anterior part it is covered by the dorsal nucleus of the eighth nerve, and is more deeply placed and a little further from the middle line than behind. The *funiculus solitarius* passes downwards by the outer side of the nucleus, but its inferior extremity has not yet been satisfactorily determined; it may be compared to the retroserial root of the fifth nerve. The efferent fibres of the nerve take origin from the anterior or cerebral extremity of the *nucleus ambiguus*, a mass of grey matter which lies in the reticular formation of the fourth ventricle; it is co-extensive with the nucleus of the ala cinerea, but is more deeply placed in the medulla.

The nerve passes outwards to the jugular foramen, through which, in a separate tube of dura mater in front and to the outer side of that which contains the vagus and spinal accessory trunks, it leaves the skull. As it is passing through the foramen, it presents two ganglionic enlargements, the jugular and petrous ganglia. The *jugular ganglion* is situated in the upper part of the foramen; it is very small and embraces only a few of the fibres of the nerve; it gives off no branches, and is sometimes absent altogether. The *petrous ganglion* lies in a groove of the petrous bone, and measures about a fourth of an inch in length; it gives off three or four small connecting branches and the tympanic branch.

On emerging from the foramen, the nerve appears between the internal jugular vein and the internal carotid artery, and passes downwards and

forwards on the deep surface of the stylo-pharyngeus muscle, crossing between the external and internal carotid arteries; it then turns over the lower border of the stylo-pharyngeus and passes forwards on its surface, and on the deep surface of the hyo-glossus, to the back of the tongue, where it divides into its terminal branches. On its way it supplies the stylo-pharyngeus muscle, and detaches some pharyngeal branches and a tonsillar branch.

Connecting branches. From the petrous ganglion three slender communicating branches are given off; one of these passes to the *superior cervical ganglion of the sympathetic*, another joins the *auricular branch of the vagus*; the third passes to the *ganglion of the root of the vagus.* From the trunk of the nerve a little below the ganglion a communicating twig is given to *the facial* or to its stylo-hyoid branch.

The **tympanic branch** or **nerve of Jacobson** springs from the petrous ganglion; it enters a minute canal which opens between the jugular foramen and carotid canal, and is conducted to the tympanic cavity, on the inner wall of which it ascends, grooving the surface of the promontory, and breaking up into a number of branches which form the *tympanic plexus.* The branches of the plexus ramify in the mucous membrane, passing forwards to the posterior portion of the Eustachian tube and backwards to the mastoid cells. From the plexus, a branch, the *small superficial petrosal nerve*, which may be regarded as the continuation of the nerve of Jacobson, passes forwards and, receiving a communicating branch from the geniculate ganglion of the facial, pierces the superior surface of the petrous bone, courses beneath the dura mater, external to the hiatus Fallopii, and passes through the petro-sphenoidal fissure to join the otic ganglion. Another branch, the *small deep petrosal nerve*, passes forwards from the plexus along a canal beneath the tensor tympani muscle to join the carotid plexus of the sympathetic and the great deep petrosal nerve, which passes to Meckel's ganglion. In addition, one or two small branches pierce the anterior tympanic wall and join the carotid plexus.

Pharyngeal branches. These are given off a little below the ganglion; they are three or four in number. One or two of them, of small size, pass directly to the mucous membrane of the upper part of the pharynx, piercing the superior constrictor. The largest branch descends a little to join the pharyngeal branch of the vagus, along with which and one or two branches from the superior cervical ganglion of the sympathetic, it ramifies over the middle constrictor, forming the *pharyngeal plexus.* From the plexus branches proceed to the mucous membrane of the pharynx, and to the constrictor muscles, the palato-glossus muscle, and the palato-pharyngeus muscle. In addition the levator palati and azygos uvulae muscles probably receive their supply through the pharyngeal plexus (see p. 546). One or two branches usually pass from the plexus to the superior laryngeal branch of the vagus, and a communicating twig joins the hypoglossal nerve.

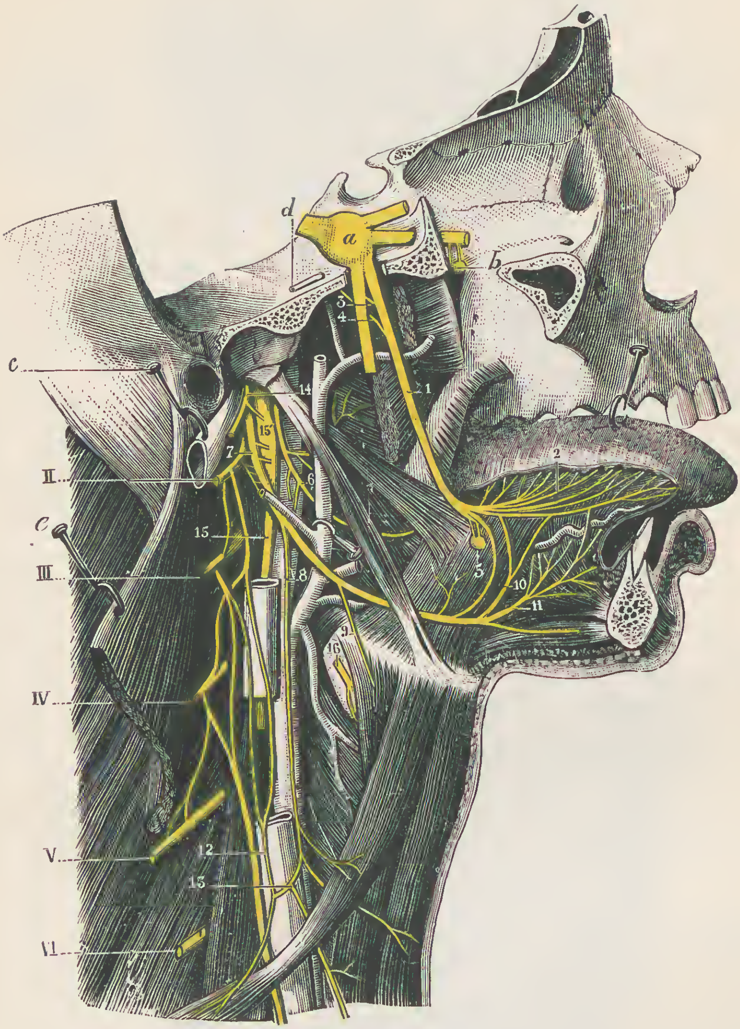

Fig. 411.—The External and Internal Carotid Arteries and their Chief Relations. II. to VI., Cervical nerves (anterior divisions). *a*, Gasserian ganglion; *b*, Meckel's ganglion; *c*, internal jugular vein; *d*, middle meningeal artery; *e*, sterno-mastoid muscle. 1, 2, Lingual nerve; 3, connecting branch between lingual and inferior dental; 4, chorda tympani; 5, submaxillary ganglion; 6, glosso-pharyngeal nerve; 7, hypoglossal nerve; 8, descendens hypoglossi: 9, thyro-hyoid branch; 10, connections between lingual and hypoglossal; 11, terminal branches of hypoglossal; 12, communicating branches from cervical plexus; 13, ansa hypoglossi; 14, spinal accessory; 15, pneumogastric; 15′, ganglion of the trunk of the pneumogastric; 16, superior laryngeal nerve. (L. Testut.)

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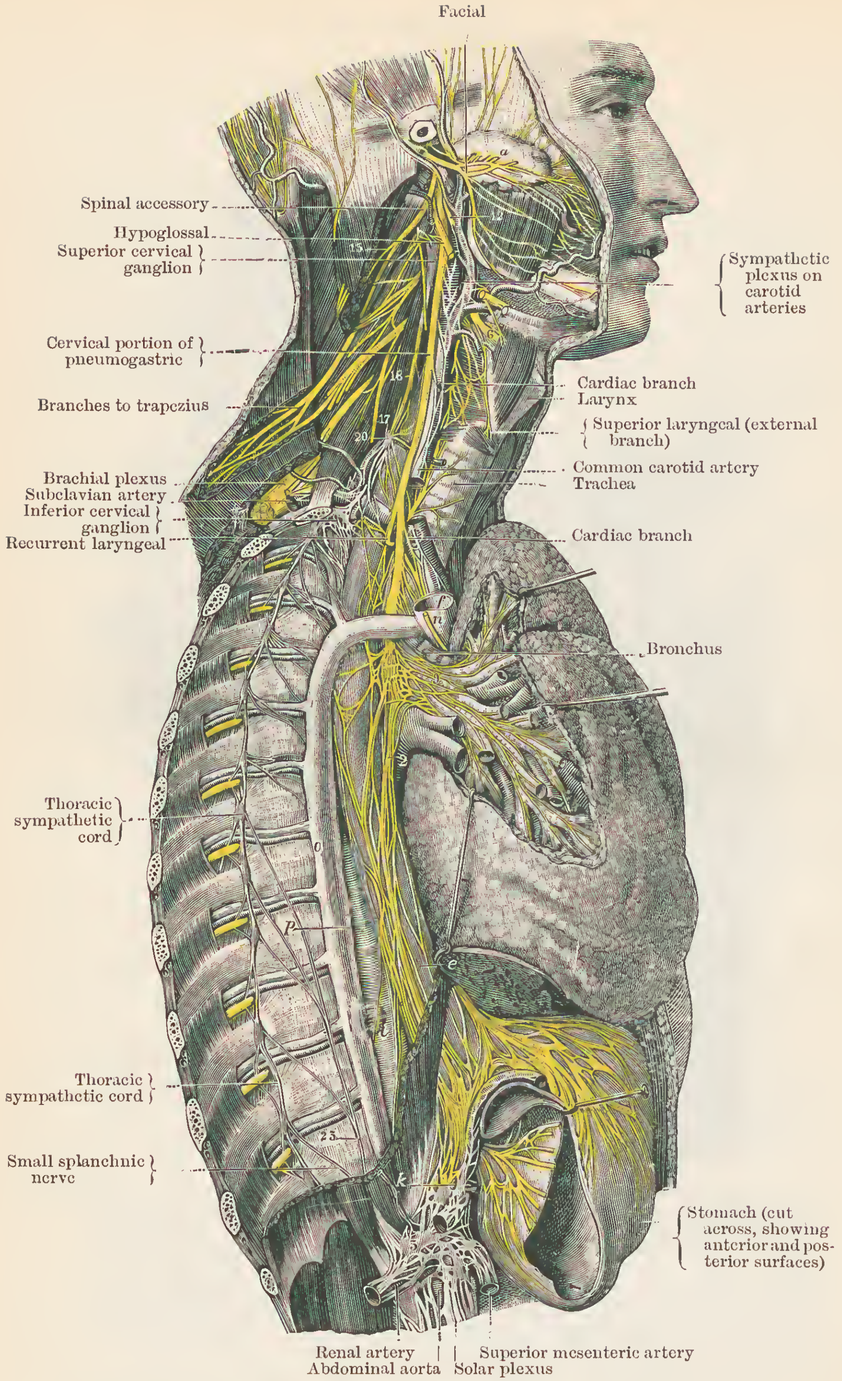


FIG. 412.—THE PNEUMOGASTRIC AND SYMPATHETIC NERVES OF THE RIGHT SIDE. *a*, Parotid gland, turned upwards; *e*, oesophagus; *i*, thoracic aorta; *k*, coeliac axis; *n*, vena cava superior; *o*, great azygos vein; *p*, thoracic duct: 2, thoracic portion of pneumogastric; 3, semilunar ganglion; 6, superior laryngeal (internal branch); 9, posterior pulmonary plexus; 12, glosso-pharyngeal; 15, branches to sterno-mastoid; 17, phrenic; 18, cervical sympathetic cord; 20, middle cervical ganglion; 23, great splanchnic nerve. (L. Testut.)

To face p. 555.

A little below the place of origin of the pharyngeal nerves one or more slender **muscular branches** are detached to the *stylo-pharyngeus.*

Near the tongue one or two **tonsillar branches** are given off; these ramify over the tonsil and the anterior pillar of the fauces.

Glossal branches. Of the terminal branches one, the *dorsal branch,* is distributed to the circumvallate papillae, and the posterior third of the tongue extending backwards to the epiglottis; the other, the *lateral branch,* ramifies over the side of the posterior half of the tongue.

THE TENTH NERVE, THE VAGUS OR PNEUMOGASTRIC.

The pneumogastric nerve (Fig. 412) arises immediately behind the glosso-pharyngeal nerve from the groove on the side of the medulla between the olivary and restiform bodies, by several fasciculi which unite with one another to form a single stem.

Nuclei of origin. Within the substance of the medulla the fibres are connected with the nucleus of the ala cinerea and the nucleus ambiguus already described in connection with the ninth nerve; a few join the funiculus solitarius.

From its place of origin the vagus is directed outwards to the foramen jugulare through which, in company with the spinal accessory nerve, it leaves the cranium. In the foramen it presents a small ganglion about a sixth of an inch in diameter, *the ganglion of the root.* As it emerges from the foramen it appears between the internal carotid artery and internal jugular vein; the glosso-pharyngeal nerve is in front of it; the spinal accessory is behind; and the hypoglossal nerve, at first on its deep surface, winds round its posterior border, and is closely connected with it. In this situation the nerve swells into a second and larger ganglion, the *ganglion of the trunk* (*plexus nodosus*). Descending in the neck the vagus occupies a special compartment in the carotid sheath and lies on the deep surface of and between the artery and vein. From the root of the neck, on account of the want of symmetry of the parts in the upper region of the thorax, the course and relations of the nerves of the opposite sides must be separately traced. The *nerve of the right side* descends in front of the first part of the subclavian artery, and detaches its recurrent branch, which passes upwards behind the artery. It then enters the thorax behind the innominate vein and descends to the posterior surface of the root of the lung. Behind the root it forms a flattened cord from which numerous branches, forming the posterior pulmonary plexus of the right side, pass outwards to the lung. Below the root, the nerve divides into two branches which descend upon the side of the oesophagus, detaching to one another and to the corresponding cords of the opposite side communicating branches which form the oesophageal plexus. Near the diaphragm the two cords reunite and form a single trunk which passes through the oesophageal opening and ramifies on

the posterior surface of the stomach. The *left nerve* enters the thorax between the carotid and subclavian arteries, crosses in front of the arch of the aorta, and gives off its recurrent branch, which passes upwards behind the arch. It then gains the back of the root of the left lung and detaches branches which form the left posterior pulmonary plexus. Afterwards it descends as two cords upon the left side of the oesophagus and takes part in forming the oesophageal plexus. It passes through the oesophageal opening of the diaphragm as a single trunk and ramifies over the front of the stomach.

Communicating branches. The most important communicating branch which the vagus receives is the *accessory portion of the spinal accessory nerve*; this cord gives one or two filaments to the ganglion of the root and then joins the ganglion of the trunk; most of its fibres pass into the pharyngeal and superior laryngeal nerves, but some descend in the trunk of the vagus. The *glosso-pharyngeal nerve* is connected with the vagus by a twig which joins the ganglion of the root. The *hypoglossal nerve* exchanges some fibres with the ganglion of the trunk. The first cervical ganglion of the *sympathetic* and the first loop of the *cervical plexus* also communicate with the ganglion of the trunk.

The **meningeal branch**, a slender twig, arises from the ganglion of the root, and is distributed to the dura mater in the vicinity of the jugular foramen.

The **auricular branch**, the nerve of Arnold, a delicate nerve, arises from the ganglion of the root; it passes in front of the upper end of the internal jugular vein, enters a small canal in the jugular fossa, traverses the temporal bone, crossing the inner surface of the aqueduct of Fallopius, and appears at an opening on the surface of the mastoid, behind the external auditory meatus. It is connected by communicating branches with the glosso-pharyngeal and facial nerves. Terminally, it divides into two branches, one of which supplies the back of the pinna and the meatus, while the other joins the auricular branch of the facial nerve.

The **pharyngeal branches**, one or two in number, arise from the ganglion of the trunk; their fibres are chiefly continued from the accessory portion of the spinal accessory nerve. They join the pharyngeal branches of the glosso-pharyngeal and sympathetic nerves to form the pharyngeal plexus (p. 554).

The **superior laryngeal nerve** springs from the ganglion of the trunk, and contains a number of fibres from the accessory portion of the spinal accessory nerve. It is the sensory nerve of the greater part of the larynx, and it supplies the crico-thyroid muscle, and gives a twig to the inferior constrictor. It passes downwards and forwards on the deep surface of the internal carotid artery, communicates with the sympathetic and the pharyngeal plexus, and divides into an internal and an external branch. The *internal branch*, the *internal laryngeal nerve*, accompanies the laryngeal branch of the superior thyroid artery, pierces the thyro-hyoid membrane, and is

distributed to the mucous membrane from the base of the tongue and the epiglottis downwards as far as the true vocal cord, and also to that covering the back of the cricoid cartilage; on the deep surface of the ala of the thyroid cartilage it communicates with the inferior laryngeal nerve. The *external branch*, the *external laryngeal nerve*, a slender twig, descends on the deep surface of the infrahyoid muscles, and is distributed to the crico-thyroid muscle and the inferior constrictor of the pharynx; it also gives off one or two slender branches to the mucous membrane of the larynx, and it usually detaches a branch which joins one of the cardiac branches of the sympathetic.

The **recurrent** or **inferior laryngeal nerve** is the chief motor nerve of the larynx, but also supplies sensory filaments to the region below the vocal cord; in addition it furnishes branches to the cervical portions of the trachea and oesophagus. The *nerve of the right side* arises in the lower part of the neck; it bends round and ascends behind the first part of the subclavian artery, then passes upwards and inwards behind the common carotid and inferior thyroid arteries to gain the angle between the oesophagus and trachea in which it continues its ascent. It is connected with the inferior cervical ganglion of the sympathetic nerve, and supplies *oesophageal* and *tracheal branches*, and gives some twigs to the inferior constrictor. It enters the larynx beneath the edge of the inferior constrictor muscle, supplies all the muscles of the larynx except the crico-thyroid, ramifies in the mucous membrane of the region below the true vocal vord, and forms a communication with the superior laryngeal nerve. The *nerve of the left side* arises in the thorax, arches round the aorta, and then ascends into the neck behind the subclavian artery. It gives off a cardiac branch as it is passing beneath the aorta; its subsequent course in the neck and its distribution are similar to those of the nerve of the right side.

The **cardiac branches** are three or four in number, and are subject to considerable variation. One or two arise in the upper part of the neck from the main stem and from the external laryngeal branch; descending they join with the cardiac nerves from the cervical sympathetic. One arises in the lower part of the neck, and one takes origin in the thorax from the main trunk on the right side and from the recurrent nerve on the left side. They all join the deep cardiac plexus, with the exception of the lowest cervical branch of the left side, which crosses in front of the arch of the aorta to end in the superficial cardiac plexus.

Two or three **anterior pulmonary branches** of slender size arise in the upper part of the thorax; they pass to the front of the root of the lung, and join with branches of the sympathetic nerves to form the delicate *anterior pulmonary plexus* which ramifies upon the front of the root.

The **posterior pulmonary branches** are numerous and of large size. They are given off behind the root of the lung, and, communicating with one another and with a few delicate sympathetic branches from the higher thoracic ganglia, form the *posterior pulmonary plexus*, the branches of which

ramify with the bronchi in the lungs. The plexuses of opposite sides communicate with one another.

The **oesophageal branches** communicate with one another and with those of the nerve of the opposite side forming the *oesophageal plexus* from which branches pass to the muscular wall and mucous membrane of the thoracic portion of the oesophagus.

The terminal or **gastric branches** ramify upon the stomach, and form communications with the sympathetic. The *nerve of the left side* is chiefly distributed to the front of the stomach. In the neighbourhood of the small curvature it forms communications with the nerves of the posterior surface, and furnishes branches to the hepatic plexus of the sympathetic. The *nerve of the right side* is chiefly distributed to the posterior surface of the stomach, and gives communicating branches to the coeliac plexus of the sympathetic.

Development. The recurrent course of the inferior laryngeal branch can be accounted for on developmental grounds. At an early stage in the embryo the nerve passed inwards to the larynx below the lowest of the primary vascular arches; by the descent of the heart and the great vessels from the neck into the thorax the nerve was drawn downwards. The distribution of the nerves of the right and left sides respectively to the posterior and anterior surface of the stomach was brought about in the course of development by a change in position of the stomach, which originally projected forwards in the middle line, but afterwards became turned over on to its right side.

THE ELEVENTH OR SPINAL ACCESSORY NERVE.

The spinal accessory nerve (Fig. 412) is formed of two distinct portions, respectively bulbar and spinal in origin. The bulbar portion, the smaller of the two, springs by five or six roots, which are in continued series with those of the vagus. The spinal portion arises by a number of fasciculi, which spring from the side of the upper part of the spinal cord between the anterior and posterior nerve roots, in the region above the level of origin of the sixth cervical nerve; the lower of the fasciculi emerge from the cord immediately behind the line of attachment of the ligamentum denticulatum; the higher ones, more posteriorly placed, are close to the posterior roots. Gradually increasing in size the nerve ascends behind the ligamentum denticulatum, and enters the cranium through the foramen magnum. It is then joined by the bulbar portion, and the common trunk passes outwards behind the vagus to the jugular foramen. Immediately beneath the jugular foramen the component parts of the nerve separate from one another.

Nuclei of origin. The fibres of the bulbar portion are in the medulla oblongata connected with the posterior extremity of the nucleus ambiguus, from which the efferent fibres of the vagus spring; those of the spinal portion take origin from a group of cells, which in the lower cervical

region lies at the base of the anterior horn, but which, when followed upwards, gradually assumes a more ventral position.

The **bulbar or accessory portion** joins the ganglion of the trunk of the vagus; and most of the fibres pass into the cardiac, inferior and superior laryngeal, and pharyngeal branches. The fibres which it conveys to the vagus are believed to be partly cardiac inhibitory and partly motor for the muscles of the larynx and pharynx and some of those of the palate.

The **spinal portion** (Fig. 379) assists in the supply of the sterno-mastoid and trapezius muscles. It passes backwards and downwards, crossing, as a rule, the deep surface of the internal jugular vein, and lying between the posterior belly of the digastric muscle and the transverse process of the atlas. Continuing its course it passes through the sterno-mastoid muscle, crosses obliquely the posterior triangle of the neck, and gains the deep surface of the trapezius, upon which it descends, gradually diminishing in size as its branches enter the muscle. On the deep surface of the sterno-mastoid it is joined by a branch of the second cervical nerve, and on the deep surface of the trapezius by two or three branches from the third and fourth cervical nerves.

THE TWELFTH OR HYPOGLOSSAL NERVE.

The hypoglossal nerve (Fig. 413) takes origin by ten or twelve root bundles which spring from the side of the medulla oblongata in the furrow between the anterior pyramid and the olivary body.

Nucleus of origin. The fibres spring from a large nucleus which lies close to the middle line, beneath the floor of the hinder part of the fourth ventricle, and extends backwards through the closed portion of the medulla, along the ventro-lateral margin of the central canal, to become continuous with the anterior cornu of the spinal cord.

The several fasciculi of origin are directed outwards from the surface, and become gathered into two bundles; these separately pierce the dura mater and enter the anterior condylar foramen, within which they unite with one another. After emerging from the foramen the nerve becomes adherent for a short distance to the posterior border of the lower ganglion of the vagus. It then passes between the internal carotid artery and the internal jugular vein. In its subsequent course the nerve forms a bend with the convexity downwards. It passes at first downwards and forwards to within a short distance of the great cornu of the hyoid bone, crossing the internal carotid artery, escaping from the cover of the posterior belly of the digastric, looping round the occipital artery, and crossing the external carotid artery. It then runs forwards above the great cornu, passing on the deep surface of the tendon of the digastric, and resting on the hyo-glossus muscle. Its terminal branches ascend upon the hyo-glossus and the genio-glossus to the tongue.

As it is leaving the skull the nerve detaches a small *meningeal branch.*

Immediately below the foramen of exit the hypoglossal is joined by **communicating branches** from the *first loop of the cervical plexus*, and from the *superior cervical ganglion of the sympathetic*; there is also an interchange of fibres between it and the *ganglion of the trunk of the vagus* as they adhere to one another below the base of the skull. A little lower down a branch from the *vagus* or from the *pharyngeal plexus* joins the trunk of the nerve. As it rests upon the hyo-glossus, before it breaks up into its terminal branches, two or three filaments pass between it and the *lingual branch of the fifth nerve.*

The **branches of distribution** supply the intrinsic muscles of the tongue and the stylo-glossus, hyo-glossus, genio-glossus, genio-hyoid, and thyro-hyoid, and the anterior belly of the omo-hyoid; in addition they furnish part of the supply of the posterior belly of the omo-hyoid, the sterno-hyoid, and the sterno-thyroid. It is usual among mammals for all the muscles below the hyoid bone to be supplied altogether by the spinal nerves, and it is quite probable that in man the nerve fibres to these muscles have a similar origin, those detached from the hypoglossal possibly reaching it through the connecting branches with the cervical plexus.

The *descending branch* (descendens hypoglossi, descendens noni in the system of Willis) arises as the main trunk is looping round the occipital artery; it passes downwards and forwards upon the surface of the carotid sheath, and detaches a twig to the anterior belly of the omo-hyoid. It is then joined by a branch (the communicans hypoglossi) which springs by two roots from the second and third cervical nerves respectively; from the loop which is thus formed (the ansa hypoglossi) branches pass to the sterno-hyoid, sterno-thyroid, and the posterior belly of the omo-hyoid; occasionally a branch from the loop extends into the thorax, and communicates with the phrenic nerve. The descending branch sometimes springs from the vagus instead of the hypoglossal, and it may run for some distance within the carotid sheath. The *nerve to the thyro-hyoid*, a slender twig, is detached from the hypoglossal as it bends forwards below the posterior belly of the digastric.

The *nerves to the stylo-glossus*, *hyo-glossus*, *genio-glossus*, and *genio-hyoid* are slender branches, which are given off as the main stem rests on the hyo-glossus muscle. The *terminal* or *glossal branches* pierce the under surface of the tongue.

THE SYMPATHETIC NERVES.

The central part of the sympathetic system is formed of two *gangliated cords*, one on each side of the body, which run through the whole length of the trunk by the side of the vertebral column, and are sometimes called the prevertebral chains. In the thoracic region there are usually twelve ganglia on each side, one corresponding to each segment, but the number is liable to diminution on account of the occasional conjunction of neighbouring

ganglia; in the cervical region the number of ganglia is reduced to three; there are four or five lumbar and four sacral ganglia, and the chains of opposite sides terminate in a median ganglion impar on the front of the coccyx. The ganglia of the great sympathetic cords may be termed the *proximal ganglia*, and they are to be distinguished from other more distally placed *secondary* or *distal ganglia* which are found scattered among the branches of the cords.

The proximal ganglia are connected with the anterior divisions of the spinal nerves by branches which are styled the *rami communicantes*. These communicating branches are of two kinds, which are named respectively *white* and *grey* branches of communication. The *white rami* are formed of medullated fibres of small diameter; they may be regarded as the sole roots of the sympathetic system. They contain both efferent and afferent fibres, and are probably limited to the thoracic and the upper part of the lumbar region; their fibres, running in the anterior and posterior roots of the spinal nerves, pass between the thoracic and upper lumbar proximal ganglia and the spinal cord. It is to be added, however, that from the second, third, and fourth sacral nerves fibres similar to those which form the white roots pass outwards and, instead of joining the proximal ganglia of the main cord, run directly to the distal ganglia of the pelvic plexus of the sympathetic. Many of the cranial nerves contain fibres which are to be compared to those of the sympathetic system. The *grey rami* are branches of distribution from the sympathetic ganglia; they are formed chiefly of non-medullated fibres; one passes to each of the spinal nerves. On reaching the spinal nerve the grey fibres of the ramus break up into two divisions; one of these, the smaller, passes backwards and ramifies on the sheaths of the spinal cord, the other turns outwards with the spinal nerve, and is distributed peripherally. The very few white fibres which are found in the grey rami are probably afferent sympathetic fibres, and enter the cord by the white roots.

The *longitudinal cord of the sympathetic* of each side is formed from a series of commissures which pass between the successive ganglia; from the ganglia of the thorax and upper lumbar region, which receive the white roots, the fibres stream upwards into the neck and downwards into the pelvis.

Branches. In addition to the grey rami, which are distributed to the body wall, there are given off in the neck, thorax, and upper part of the abdomen, numerous visceral branches, the most important of which are the cardiac and splanchnic nerves; they form large plexuses containing ganglia; from the plexuses smaller plexuses are prolonged to the viscera and visceral bloodvessels, and these in their turn frequently contain ganglia. The efferent fibres of the sympathetic have various functions. To the heart and bloodvessels there pass fibres which are termed *vaso-motor*; their stimulation causes acceleration of the heart

beat, and contraction of the bloodvessels. Another set of fibres, which are termed *vaso-inhibitory*, are distributed to the heart and vessels; the inhibitory fibres for the heart, however, run in the vagus nerve; and those for some of the vessels of the head, *e.g.* those of the salivary glands, are found in certain of the cranial nerves; the nervi erigentes, the stimulation of which dilates the vessels of the genital organs, are known to arise from the second and third sacral nerves, and to join the pelvic plexuses of the sympathetic; the course of the inhibitory fibres for the other vessels is not known. To the muscular layers of the viscera there pass fibres, stimulation of which induces contraction, they may be called viscero-motor; the *viscero-motor fibres*, for nearly the whole length of the alimentary canal, run in the vagus and its associated nerves, but those for the pelvic portion of the tube and the other pelvic viscera probably run partly in the splanchnic trunks, and partly along with the nervi erigentes from the sacral nerves to the pelvic plexus. Most physiologists agree that there are also *viscero-inhibitory fibres*, stimulation of which inhibits the contraction of the muscular tissue of the viscera; the course of these fibres is not known, but it is probable that those for the abdominal portion of the alimentary canal run in the splanchnic nerves. *Glandular fibres* pass from the sympathetic to the salivary and sweat glands, and possibly to other glandular organs. Those for the salivary glands ascend in the cervical sympathetic and pass out from the superior cervical ganglion; they carry impulses which affect the processes which take place in the glands. The fibres for the sweat glands probably pass through the grey rami, and are distributed with the nerves which run in the body wall; their stimulation produces an increase in the secretion of sweat. *Pilo-motor fibres* pass to the muscles of the hair follicles; their course is probably similar to that of the fibres for the sweat glands. *Dilator fibres for the pupil* ascend in the cervical sympathetic and the cavernous plexus to the ciliary ganglion. The *afferent fibres* of the sympathetic probably come chiefly from the abdominal and pelvic viscera through the splanchnic nerves.

The Cervical Portion of the Gangliated Cord.

The cervical portion of the sympathetic cord (Fig. 412) lies upon the rectus capitis anticus major and longus colli muscles, in front of the transverse processes of the vertebrae, and on the deep surface of the carotid sheath. At the root of the neck, on the right side, it descends behind the subclavian artery, but one or two offsets (ansa Vieussenii) usually cross in front of the vessel to rejoin the main stem below it. It presents three ganglia.

The **superior cervical ganglion**, the largest of the series, is somewhat spindle-shaped, measures about an inch in length, and probably repre-

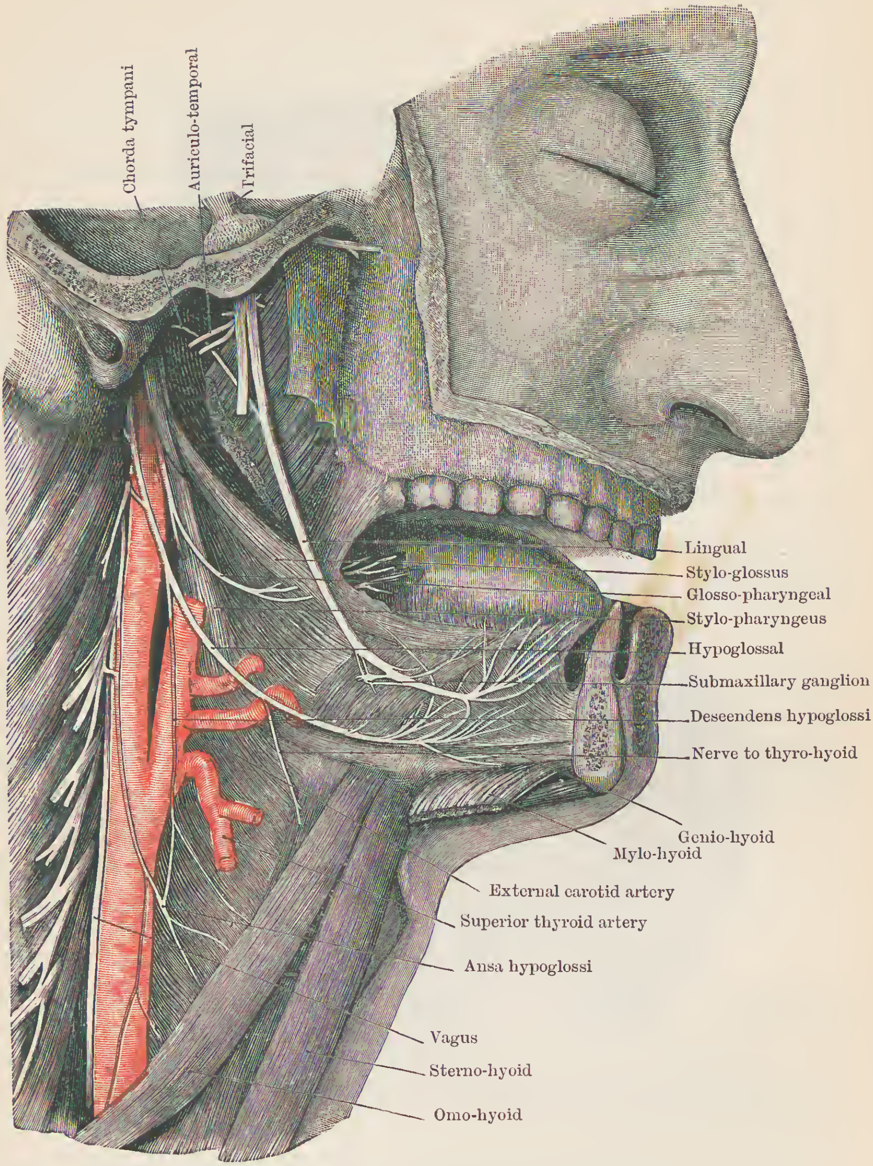


FIG. 413.—THE NERVES OF THE TONGUE. (C. Gegenbaur.)

To face p. 562.

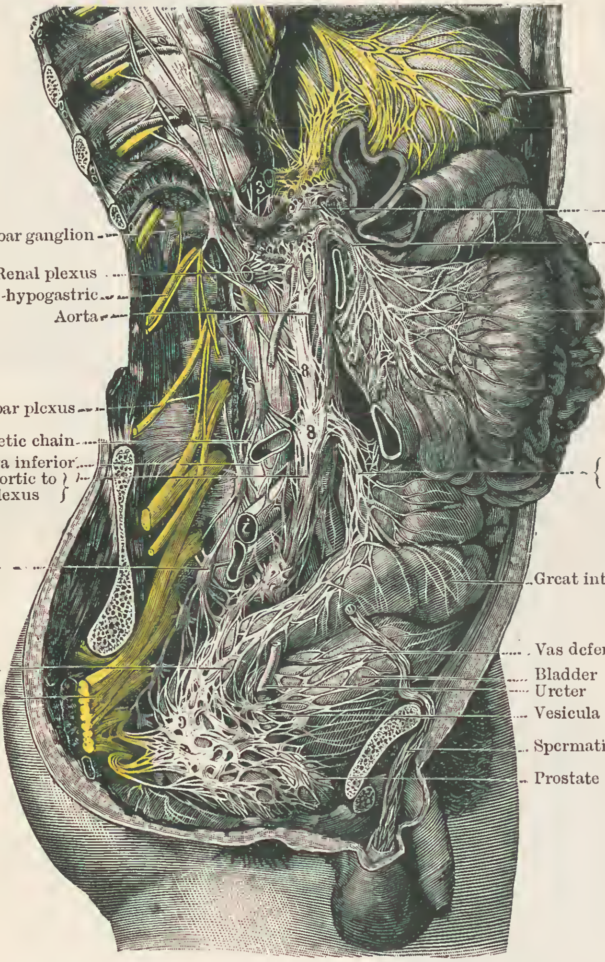


FIG. 414.—THE SYMPATHETIC OF THE LOWER PART OF THE TRUNK, right side. 3, Semilunar ganglion; 8, aortic plexus; 9, pelvic plexus. (Testut, after Hirschfeld.)

To face p. 563.

sents four ganglia, which have become united into a single mass; it is placed in front of the transverse processes of the second and third vertebrae. Its branches are the communicating, the vascular, the ascending, the pharyngeal, and the superior cardiac.

The *communicating branches* are numerous: one passes to each of the anterior divisions of the first four cervical nerves, one passes to the hypoglossal nerve, one to each of the ganglia of the vagus, and one to the petrous ganglion of the glosso-pharyngeal.

The *vascular branches* pass to the external carotid artery and ramify with its branches; some of them reach the thyroid body, others terminate in the intercarotid body; the sympathetic roots of the otic and submaxillary ganglia are detached from the vascular branches.

The *ascending branch* accompanies the internal carotid artery; it enters the carotid canal, and divides into an external and an internal branch. The *external branch* breaks up within the canal and on the outer side of the artery, into numerous subdivisions, which, interlacing and communicating with one another, form the *carotid plexus.* From the carotid plexus a number of communicating branches are given off: (*a*) one or two *tympanic branches* pierce the wall of the canal and pass between the carotid plexus and the tympanic plexus; one of these, generally regarded as passing from the tympanic plexus to the carotid plexus and the great deep petrosal nerve, is named the *small deep petrosal nerve* (p. 554); (*b*) the *great deep petrosal* crosses the foramen lacerum medium and joins the great superficial petrosal of the facial to form the Vidian nerve; (*c*) a branch joins the sixth nerve; and (*d*) a branch joins the Gasserian ganglion. The *internal branch* breaks up into the *cavernous plexus*, which lies on the under surface of the artery as it is passing forwards through the cavernous sinus; from the plexus (*a*) *vascular branches* accompany the branches of the internal carotid artery; (*b*) *communicating branches* join the third and fourth nerves, and the ophthalmic division of the fifth; (*c*) the *sympathetic root of the lenticular ganglion* passes into the orbit either separately or in conjunction with the nasal branch of the ophthalmic division of the fifth; and (*d*) small filaments pass to the pituitary body.

The *pharyngeal branches* of the superior ganglion are two or three in number; they join with the pharyngeal branches of the vagus and glosso-pharyngeal nerves to form the pharyngeal plexus (p. 554).

The *superior cardiac branch* descends by the side of the main trunk and communicates with the external and recurrent laryngeal nerves, and with the other cervical cardiac nerves; on the right side it passes in front of or behind the subclavian artery and joins the deep cardiac plexus; on the left it crosses in front of the aortic arch, and terminates in the superficial cardiac plexus.

The **middle cervical ganglion** is much smaller than the superior, and is sometimes absent altogether; it is probably formed from two originally separate ganglia. It is placed opposite the sixth cervical

vertebra, and generally rests upon the inferior thyroid artery. It detaches (*a*) *communicating branches* to the anterior divisions of the fifth and sixth cervical nerves, (*b*) *vascular branches* with the inferior thyroid artery to the thyroid body, and (*c*) the *middle cardiac branch*, which on each side descends to the deep cardiac plexus; the left nerve enters the thorax behind and to the inner side of the subclavian artery; the nerve of the right side crosses the subclavian either on its superficial or its deep aspect.

The **inferior cervical ganglion**, intermediate in size between the superior and middle, lies between the last cervical transverse process and the neck of the first rib; it probably represents two originally separate ganglia. It detaches (*a*) *communicating branches* to the seventh and eighth cervical nerves; (*b*) *vascular branches* which ascend with the vertebral artery, forming a plexus surrounding its stem and accompanying its branches; and (*c*) the *inferior cardiac nerve*, which on each side joins the deep cardiac plexus.

The Thoracic Portion of the Gangliated Cord.

This portion (Fig. 412) descends by the side of the vertebral column, lying behind the pleura, and crossing anteriorly the intercostal vessels. It presents twelve ganglia, but the first (the ganglion stellatum) is frequently conjoined with the inferior cervical ganglion. The upper ten ganglia lie upon the heads of the corresponding ribs; the lower two rest upon the vertebral bodies. Entering the abdomen the sympathetic trunk either passes behind the internal arched ligament or pierces the crus of the diaphragm. The branches are the communicating, the vascular, the pulmonary, and the three splanchnic nerves.

Two communicating branches, respectively white and grey, pass from each ganglion to the corresponding spinal nerve. *Vascular branches* of small size pass from the first five or six ganglia to the aorta. A few *pulmonary branches* from the upper ganglia enter the posterior pulmonary plexus.

The *great splanchnic nerve* arises by separate branches from the ganglia from the fifth to the ninth or tenth; these roots bend forwards upon the column and, joining with one another, form a considerable trunk which, piercing the crus of the diaphragm, enters the abdomen and terminates in the semilunar ganglion. Before entering the abdomen the nerve of the right side frequently presents a small ganglion upon its trunk; a similar ganglion is occasionally found on the left nerve. The *middle splanchnic nerve* of small size springs from the tenth and eleventh ganglia; it passes behind the internal arched ligament and ends in the solar plexus. The *smallest splanchnic nerve* springs from the twelfth ganglion; it descends with the middle splanchnic and usually ends in the renal plexus. The splanchnic nerves contain many medullated fibres which, emerging by the white roots from the cord, pass over the ganglia of the main chain without being connected with their cells.

The Lumbar Portion of the Gangliated Cord.

The lumbar portion (Fig. 414) descends upon the surface of the column by the inner margin of the psoas muscle. It crosses anteriorly the lumbar vessels, and on the right side lies behind the vena cava inferior. It presents four or five ganglia.

Communicating branches pass from the ganglia to the anterior divisions of the lumbar nerves; they are longer than the corresponding branches in the dorsal region, and are less regular in their arrangement. A few branches, very irregular as to number and place of origin, pass to the aortic and hypogastric plexuses.

The Sacral Portion of the Gangliated Cord.

This portion (Fig. 414) descends in front of the sacrum by the inner margins of the anterior foramina; it presents usually four small ganglia, and the cords of the opposite sides terminate in a median *ganglion impar*, which lies upon the last piece of the sacrum or on the coccyx. Irregular *communicating branches* pass to the anterior divisions of the sacral nerves. A few small twigs reach the pelvic plexus, and from the ganglion impar branches proceed to the coccygeal gland.

The Cardiac Plexus.

The cardiac plexus lies below and behind the arch of the aorta. It is formed by the interlacement of the cardiac branches of the vagus and sympathetic nerves. From the trunk of the vagus on each side three cardiac branches are given off in the neck; and a cardiac branch is detached in the thorax usually from the main trunk upon the right side and from the recurrent laryngeal nerve upon the left. The cervical sympathetic cord on each side gives off three cardiac nerves. The various branches, however, are subject to considerable irregularity. The plexus is usually described as being formed of two portions—the superficial and the deep—which are, however, continuous with one another.

The *superficial cardiac plexus* lies below the arch of the aorta, immediately to the right side of the ductus arteriosus. It receives the superior cardiac branch of the sympathetic cord of the left side, and the lowest cervical branch of the pneumogastric of the same side, and at the point of junction of the nerves a small ganglion, the ganglion of Wrisberg, is frequently found. The plexus gives off some slender branches to the left anterior pulmonary plexus, and is continued into the right coronary plexus.

The *deep cardiac plexus* lies in front of the trachea, and behind the arch of the aorta. It receives all the cardiac branches already enumerated, with the exception of the two which pass to the superficial plexus. It gives branches to both anterior pulmonary plexuses, and to the right coronary plexus, and is continued inferiorly into the left coronary plexus. The

right and left coronary plexuses accompany the right and left coronary arteries respectively; the branches, which are numerous, pierce the muscular substance of the heart, and present many microscopic ganglia. The right plexus is formed by branches from the deep and superficial cardiac plexuses; the left is continued from the deep plexus.

The Solar Plexus (Epigastric Plexus).

The solar plexus (Fig. 414), the largest of the sympathetic plexuses, rests upon the abdominal aorta at the place of origin of the coeliac axis, and stretches outwards towards the suprarenal bodies. It contains on each side a large ganglionic mass, the semilunar ganglion. The solar plexus is continued downwards on each side into the aortic plexus, and from the main plexus and its continuations there radiate a number of secondary plexuses which accompany the phrenic and visceral branches of the abdominal aorta.

The *semilunar ganglion* (see figure in description of suprarenal capsule) lies upon the crus and consists of a flattened collection of smaller ganglia closely united with one another. It measures between an inch and an inch and a half in transverse and vertical diameter, but its size varies, and some of its component smaller ganglia are frequently distinct from the main mass. It receives the great splanchnic nerve of its own side.

The *phrenic* or *diaphragmatic plexuses* ascend with the inferior phrenic arteries, and ramify on the diaphragm, forming connections with the branches of the phrenic nerves. On the right side there is usually a small ganglion in the phrenic plexus.

The *suprarenal plexuses* consist of a number of branches which pass into the suprarenal capsules.

The *renal plexuses* accompany the renal arteries to the kidneys. They are formed of numerous large nerves, and receive the smallest splanchnic nerves.

The *coeliac plexus* is continuous with the anterior surface of the solar plexus; it surrounds the coeliac axis, and receives communicating branches from the right pneumogastric nerve. It breaks up into smaller plexuses, which accompany the branches of the coeliac axis. Of these the *hepatic plexus* is the largest; it is joined by a branch of the left pneumogastric nerve and detaches pyloric, pancreatico-duodenal, and cystic plexuses, and bifurcates terminally with the right and left divisions of the hepatic artery. The *coronary plexus* descends with the artery upon the small curvature, and forms connections with the pneumogastric nerves and with the pyloric plexus. The *splenic plexus* passes to the spleen and detaches pancreatic and gastro-epiploic offsets with the branches of the splenic artery.

The *superior mesenteric plexus* is continued from the lower part of the solar plexus: the nerves which form it are remarkable for their white colour;

they surround the superior mesenteric artery and pass between the layers of the mesentery to the intestines.

The aortic plexuses, one on each side, are continued downwards from the lower lateral portions of the solar plexus. They descend upon the sides of the aorta, communicating with one another across the middle line in front of the vessel; they receive branches from the lumbar ganglia; and below, forming on each side a number of large cords, they cross the common iliac arteries and terminate in the hypogastric plexus. From the aortic plexuses the *spermatic* or *ovarian plexuses* are given off; they accompany the similarly named arteries.

The *inferior mesenteric plexus* is detached from the left aortic plexus; it is somewhat similar to the superior mesenteric plexus though of smaller size. The *inferior mesenteric ganglion* lies on the aorta immediately below the inferior mesenteric artery; it communicates with the aortic plexuses.

The Hypogastric Plexus.

This plexus is formed in front of the last lumbar vertebra by the union with one another of the cords continued from the right and left aortic plexuses; it also receives branches from the lower lumbar ganglia. It forms a flattened reticulated band, and usually contains no ganglia; it divides below into the right and left pelvic plexuses.

The **pelvic plexuses** (Fig. 414) lie by the sides of the rectum, and, in the female, of the vagina. They receive a few slender branches from the sacral ganglia, and are joined by twigs from the second, third, and fourth sacral nerves. Each plexus forms a considerable interlacement with a number of small ganglia. From the pelvic plexuses there are detached a number of subsidiary plexuses which pass with the branches of the internal iliac arteries to the pelvic viscera.

The *haemorrhoidal plexus* accompanies the middle haemorrhoidal artery to the rectum and communicates with the inferior mesenteric plexus and with the haemorrhoidal branches of the pudic nerve.

The *vesical plexus* passes forwards to the sides of the bladder. Connected with the vesical plexus there is in the male the *prostatic plexus*, and smaller collections of nerves ramify over the vesicula seminalis and accompany the vas deferens. From the prostatic plexus the cavernous nerves (*nervi erigentes*) pass forwards by the side of the membranous portion of the urethra to supply the cavernous tissue of the penis; the *small cavernous nerves* enter the hinder part of the cavernous bodies, the *large cavernous nerves* run forwards on the dorsum and join the dorsal nerves of the penis.

In the female, *vaginal plexuses* surround the lower part of the vaginal wall, supply its erectile tissue, and furnish branches to the clitoris. The *uterine plexus* ascends with the uterine artery and ramifies in the muscular substance of the uterus.

THE DEVELOPMENT OF THE NERVES.

The development of the nerves has not as yet been thoroughly worked out, and there is much discrepancy between the opinions of different observers. It is, however, generally conceded that the essential parts of the nerves are epiblastic in their origin. They appear to grow outwards towards the periphery, partly from the ganglia and partly directly from the brain or spinal cord. The ganglia are formed from a thickened longitudinal strip of the deep layer of the epiblast, which is formed on each side of the mid-dorsal line in the angle of junction between the epiblast of the neural groove and that of the general surface. The thickened strip is usually formed before the closure of the neural groove takes place, and it extends from the region of the fore-brain backwards to or nearly to the hinder extremity of the spinal cord. When the closure of the tube takes place, the thickened strips of the two sides lose their connection with the general epiblast, but remain for a time in continuity with the dorsal margin of the neural tube, and by their mesial margins in contact with one another. The name "neural crest" has been given to the continuous ridge thus formed, overlying the dorsal border of the medullary cylinder. The ganglia are formed as thickenings of the crest, each corresponding in position to a mesoblastic somite; and the unaltered portions of the crest continue for a while uniting the successive ganglia. The ganglia are at first connected with the dorsal margin of the neural tube, but the original continuity is soon broken through, and each comes to form an isolated mass of epiblastic cells lying by the side of the neural tube. Eventually, however, a secondary connection is established between the ganglion and the side of the cerebro-spinal cylinder. Some of the hinder ganglia in the chick are said to arise as independent swellings of the epiblast, the continuous neural crest not extending backwards over the whole length of the cord.

Development of the spinal nerves. When the separate ganglia have been established they sink in a ventral direction for a little distance between the mesoblastic somites and the side of the cord. They may be named the *primitive ganglia*; not only do they form the spinal ganglia of the posterior roots of the adult, but, according to most observers, a separated portion of each gives rise to a sympathetic ganglion. From the inner and outer extremities of the somewhat spindle-shaped spinal ganglion growth takes place. From the inner extremity of the ganglion the growing process attaches itself to the side of the spinal cord at a spot which corresponds with what will afterwards be the position of the tip of the posterior horn of the grey matter, and thus the secondary connection of the ganglion with the cord is established. The outgrowth from the outer extremity of the ganglion forms the afferent portion of the segmental nerve. The anterior roots of the nerves grow directly from the cord, from the side of which they emerge close

to the ventral margin. Extending outwards, they reach the developing posterior roots, and complete the nerves. The original nerve-fibres are delicate processes prolonged from the nerve cells; they become the axis-cylinders of distribution, and acquire medullary sheaths and connective-tissue coverings from the general mesoblast through which they run. According to His, the growth towards the periphery is slow. He describes the spinal nerves as beginning to develop in the human foetus in the fourth week, and as not having completed their growth to the tips of the extremities by the end of the eighth week.

It will be seen that this leaves much in the arrangement and distribution of the nerves which still requires explanation. The mode of growth of the immensely long axis-cylinder processes, the regular formation of plexuses, and the regularity of the supply of definite muscles or areae of skin from definite segments of the cord, have not been adequately explained. Hensen has put forward the theoretical suggestion that all nerves take their origin from a network of intercellular protoplasmic processes; and Hertwig has attempted to explain the regularity of the distribution of the trunks, by suggesting that the cutaneous nerves have arisen from a subepithelial protoplasmic network, and that the motor nerves are formed by the drawing out and subsequent growth of very delicate protoplasmic connections which, at an early date, stretched between the cells of the embryonic cord and those of the closely contiguous muscle plates. The nerve-trunks are formed, according to these theories, during the process of growth by the binding together of neighbouring protoplasmic threads in a common sheath.

The sympathetic system. Very little is known of the details of the development of the sympathetic system. The ganglia appear to originate in common with the spinal ganglia, and the longitudinal commissural bands are described as uniting the ganglia at a later period. The method of origin of the roots, the branches of distribution, and the secondary ganglia has not yet been investigated. It may be suggested, however, from a consideration of the anatomical details that (1) the efferent fibres of the white roots grow to the ganglia from the cord, inasmuch as they break up into arborizations within the ganglia; (2) that the secondary ganglia are derived from the chief ganglia, as many of the fibres of the white roots pass through the chief ganglia and terminate in the secondary ganglia; and (3) that the efferent branches of distribution grow from the ganglia as do the outgrowing afferent fibres from the spinal ganglia.

The cranial nerves. With the exception of the optic nerve, which is derived from a special lobe of the brain, the cranial nerves develop, in the majority of cases, either from the neural crest, or as direct outgrowths from the brain.

As in the case of those which are associated with the cord, the cranial ganglia lose their original connections with the dorsal border and become attached to the side of the neural axis. At their outer extremities,

however, they remain for a time close to the surface, and become attached to epiblastic thickenings, which lie at the dorsal extremities of the gill clefts. In the opinion of many observers these epiblastic thickenings detach cells which assist in forming the ganglia. The epiblastic thickenings just mentioned have been called the "rudimentary branchial sense-organs of Beard"; they appear to represent the branchial sense organs of fishes, and to be in series with the organs developed in that group along the lateral line. The development of the nerves which grow directly from the brain has not been satisfactorily studied.

The development of the olfactory and optic nerves is described along with that of the brain.

The *oculo-motor nerve* seems to develop chiefly as a direct outgrowth from the basal surface of the central organ, but evidences of embryonic ganglionic substance found in its root suggest the probability of its having been formed partly from the neural crest. The development of the *fourth nerve* has not been satisfactorily studied, but like the third it probably arises partly from the neural crest and partly directly from the brain. The *sixth nerve* probably grows directly from the ventral surface of the hind-brain.

The *fifth nerve* takes origin from a primitive cranial ganglion, and becomes connected with the side of the hind-brain. The ganglion becomes continuous externally with a lateral epiblastic thickening, and is in all probability partly formed from it. From the ganglion the ophthalmic branch grows forwards in front of the eye, and the inferior maxillary branch grows downwards into the mandibular arch; with the formation of the maxillary process the superior maxillary branch grows forwards. The development of the motor branch of the fifth is not satisfactorily determined, but according to Gaskell there are evidences in its root of a primitive ganglionic origin.

The *seventh and eighth nerves* are formed from one primitive ganglion. The epiblastic depression which forms the ear may be compared to a lateral sense organ, and the deeper layers of its wall probably assist in forming the ganglia of the auditory nerve, from which the nerve-fibres grow to the surface. The facial nerve descends along the anterior border of the hyoid arch, and detaches a branch, the chorda tympani, which runs along the posterior border of the mandibular arch, and joins the inferior maxillary trunk.

The *glosso-pharyngeal and vagus nerves* develop from primitive ganglia. The glosso-pharyngeal descends along the anterior border of the first branchial arch, and gives a small branch to the posterior border of the hyoid arch. The vagus is the nerve of the second and third branchial arches; in the tadpole it gives off the nerve of the lateral line. The *bulbar portion of the spinal accessory* is to be regarded as a portion of the vagus nerve; the development of the spinal portion has not yet been ascertained. The *hypoglossal nerve* is regarded by many as arising entirely

as a direct outgrowth from the ventral surface of the brain; but, on the other hand, the presence of a small ganglion in connection with its root, which has been discovered in the mammalian embryo by Froriep, would suggest that the nerve may partly be formed from the neural crest.

Morphology of the Nerves.

Various attempts have been made to classify the different nerve-fibres from a morphological point of view, the most interesting being that of Gaskell. This observer recognizes two great groups, "somatic" and "splanchnic," differing from one another in the size, the central connections, and the distribution of their constituent fibres. In a typical spinal nerve he finds five subsidiary groups of fibres, two of which fall into the somatic, while three appertain to the splanchnic division. The somatic groups are afferent and efferent; the afferent somatic fibres come from the epiblastic surface of the body, pass through the spinal ganglia, and are connected centrally with the extremity of the dorsal horn of the grey matter of the cord; the efferent somatic fibres take origin from the extremity of the ventral horn of the grey matter, and are distributed to all the voluntary muscles, with the exception of those which he includes in the respiratory group. The splanchnic groups he terms respectively the "sensory splanchnic," the "gangliated splanchnic," and the "non-gangliated splanchnic." The first of these is composed of afferent fibres, which belong to the sympathetic system; they pass through the spinal ganglia, and are supposed to be connected centrally with the basal portion of the dorsal horn. The "gangliated splanchnic" group he regards as arising from the cells of Clarke's column; the fibres are efferent, and pass to the sympathetic ganglia, from which in turn the various sympathetic efferent fibres emerge. The "non-gangliated splanchnic" fibres are supposed to take origin from the cells of the lateral column of grey matter; they are distributed to certain of the voluntary muscles, namely, those which belong to Sir Charles Bell's respiratory group. The dorsal roots of the spinal nerves contain the somatic and splanchnic afferent fibres; the ventral roots carry the somatic and the two forms of splanchnic efferent fibres. To the views of Gaskell it has to be pointed out in objection that the respiratory muscles of the trunk cannot be separated developmentally from the other voluntary muscles, and that it is only in the region of the head that a separation of the voluntary muscles into two groups can be effected. It may also be suggested that the term "splanchnic" is not properly applicable either to sympathetic nerve-fibres, which run in the somatic wall, as for instance those which supply the sweat glands and the muscles of the hair follicles, or to fibres which supply voluntary muscles, such as some of those of the respiratory group, which form a constituent part of the body wall.

While it is evident that the details of the development of the nervous system are not sufficiently well known to enable us to formulate a definite morphological classification of the nerves, yet an analysis of the various fibres which go to make up a typical segmental nerve of the trunk, and the collection of these fibres into groups dependent on the tissues to which they are distributed, may prove of use to the student in assisting him to remember the anatomical details. Each typical nerve springing from the cord is formed by the union of a posterior or dorsal and an anterior or ventral root, the former containing afferent and the latter efferent fibres. Connected with each nerve trunk there is found in the early embryo a ganglion which, in the course of development, becomes subdivided into a dorsal or afferent and a ventral or efferent portion. The dorsal portion becomes the *spinal ganglion*, the ventral portion the *sympathetic ganglion.* The spinal ganglion is connected to the cord by the posterior root. The sympathetic ganglion is connected to the cord by efferent fibres which run in the anterior root. Besides the efferent fibres which pass to the sympathetic ganglion, another set of efferent fibres is found in the anterior root. These fibres spring from the ventral extremity of the anterior horn of the cord, and pass to the voluntary muscles. The fibres which make up the roots of a segmental nerve may therefore be divided into three groups: (1) an afferent group forming the posterior root, and connected with the spinal ganglion; (2) an efferent group, forming part of the anterior root, and connected with the sympathetic ganglion; (3) an efferent group, non-gangliated, forming part of the anterior root, passing to the voluntary muscles. Following, but somewhat modifying the terminology of Gaskell, these groups may be named respectively: (1) *the dorsal gangliated afferent*, (2) *the ventral gangliated efferent*, (3) *the ventral non-gangliated efferent.*

Tracing now to their distribution the various fibres which a complete segmental nerve might be conceived to contain, they may be arranged with reference to the special groups, as follows:

1. Fibres of the dorsal gangliated group (afferent).
   (*a*) To epiblastic and hypoblastic surfaces (nerves of general and special sense).
   (*b*) To general mesoblast (afferent fibres from heart, genito-urinary organs, etc.).
   (*c*) To organs derived from the muscle plates, the voluntary muscles (the nerves of muscular sensibility).
2. The fibres of the ventral gangliated group (efferent).
   (*a*) To epiblastic and hypoblastic surfaces (glandular nerves).
   (*b*) To general mesoblast (vaso-motor, viscero-motor nerves, etc.).
3. The fibres of the ventral non-gangliated group (efferent)
   (*c*) To organs derived from the muscle plates (the motor nerves of

the voluntary muscles of trunk). The limb muscles in the lower forms are, like the muscles of the trunk, derived from the muscle plates. This has not been made out for the higher forms, but the nerves of the limb muscles in the higher classes seem to belong to the same group as those of the trunk muscles).

The segmental nerve divides almost immediately on its formation into two portions, to which the names "spinal" and "sympathetic" have been given. The spinal portion contains the afferent epiblastic fibres, the afferent fibres of the voluntary muscles, and the efferent fibres of the voluntary muscles; the sympathetic portion, known as the white root, or white ramus communicans, of the sympathetic ganglion, probably contains all the other fibres, namely, those of the ventral gangliated group and the afferent fibres of the hypoblast and the general mesoblast. Immediately after the formation of the spinal and sympathetic portions, a rearrangement of fibres takes place, which results in the formation of the nerve trunks of distribution, which may be called "somatic" and "splanchnic." The rearrangement is brought about by the passage of fibres, the so-called grey root or grey ramus communicans, from the sympathetic ganglion to the spinal nerve. The resulting somatic nerve trunk runs in the somatopleuric wall, and contains all the afferent and efferent somatopleuric fibres; the remaining splanchnic trunk ramifies in the visceral wall, and contains all the splanchnic fibres. The following diagram shows the arrangement described above. In connection with the diagram, it has to be noted

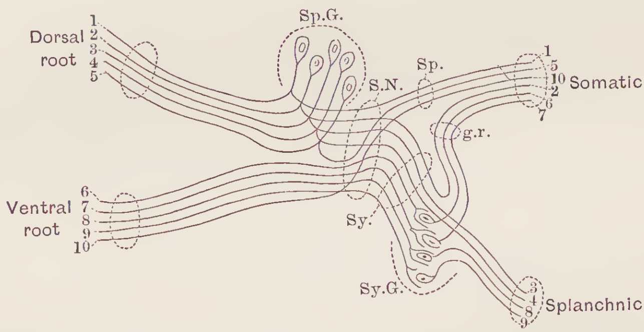


FIG. 415.—Diagram representing the probable course of the various kinds of fibres in a hypothetically complete Segmental Nerve (spinal region). 1, Epiblast afferent fibre; 2, 3, mesoblast afferent fibres; 4, hypoblast afferent fibre; 5, muscle plate afferent fibre; 6, epiblast efferent fibre; 7, 8, mesoblast efferent fibres; 9, hypoblast efferent fibre; 10, muscle plate efferent fibre. *Sp.G.*, Spinal ganglion; *S.N.*, segmental nerve; *Sp.*, spinal portion of the segmental nerve (what is usually called the spinal nerve); *Sy.*, sympathetic portion (white ramus communicans with sympathetic); *g.r.*, gray ramus communicans; *Som.*, somatic trunk running in body wall; *Spl.*, splanchnic trunk running in splanchnopleur; *Sy.G.*, Sympathetic ganglion. (J.Y.M.)

that the efferent fibres which pass to the sympathetic have been represented as if they all terminated in the ganglion of the main chain of the sympathetic. Actually, however, a number of them pass

through the ganglion of the sympathetic chain, and terminate in arborizations within one or other of the secondary ganglia. While the description above given deals with the arrangement of fibres in a hypothetically complete segmental nerve it is to be noted that probably the cervical, and the lower lumbar, and some of the sacral nerve roots, do not contain any sympathetic portion.

The somatic branches show in their origin and distribution a regular segmental type. The splanchnic or visceral branches, on the other hand, exhibit but little evidence of a segmental arrangement. On the one side of the sympathetic ganglia the branches of connection with the cord or white rami have been found in a number of mammals experimentally investigated, particularly in the dog, cat, and rabbit, to occur only in the thoracic and upper lumbar regions; on the other side of the ganglia, the somatic branches of distribution or grey rami are regular and segmental in their arrangement.

The nerves which spring from the brain cannot, like those which take origin from the cord, be clearly arranged in correspondence with a series of consecutive segments; their fibres, however, may be classified as belonging to groups which are to be compared to the dorsal gangliated afferent, the ventral gangliated efferent, and the ventral non-gangliated efferent groups of a typical segmental nerve. In studying the arrangement and distribution of the fibres it is to be remembered that the only muscles of the head which are formed from structures homologous to the mesoblastic somites are those of the orbits. The muscles of mastication and the facial muscles are formed in the lateral mesoblast. Certain of the cranial efferent nerves, the fibres of which, from their distribution to glandular structures, and to muscles developed from the general mesoblast, seem to correspond to those of the ventral gangliated group of a spinal nerve, have, in the adult, no ganglia in connection with their roots; but in each of these instances traces of ganglionic substance have been found in the embryo, suggesting an origin from a primitive ganglion, and in connection with the branches of distribution one or more distal ganglia are found in the adult.

The following classification of the cranial nerves must be regarded as purely a hypothetical one; it differs in a number of points from that put forward by Gaskell. The third, or oculo-motor, nerve is chiefly made up of fibres which correspond to those of the non-gangliated efferent group of a typical segmental nerve. It supplies muscles which are formed from the first mesoblastic somite of the head. Its fibres to the ciliary ganglion and from thence to the ciliary muscle probably correspond to those of the gangliated efferent group of fibres of a segmental nerve. Gaskell has discovered in its trunk traces of embryonic ganglionic substance. In comparing the third to a typical segmental nerve, it is to be noted that afferent fibres are wanting, those corresponding to gangliated efferent are few in number, and that those corresponding to the non-gangliated efferent form

the bulk of the nerve. The fourth nerve supplies the superior oblique muscle, which is formed from the second mesoblastic somite of the head. Its fibres are to be compared to those of the ventral non-gangliated group of a segmental trunk. As in the case of the third, Gaskell has discovered in the fourth nerve traces of ganglionic substance, which may perhaps represent an original dorsal afferent portion. The fifth nerve is formed of two portions; the fibres of the larger afferent portion correspond to those of the dorsal group, while those of the smaller efferent portion are to be compared to those of the ventral gangliated group of a segmental nerve trunk. The motor portion of the nerve is distributed to muscles which are formed in the general mesoblast; its fibres form connections with the otic ganglion; and it is interesting to note that Gaskell has discovered in its trunk, as in that of the third nerve, the remains of ganglionic substance.

The fibres of the sixth nerve seem to be comparable to those of the ventral non-gangliated group; they supply the external rectus muscle, which is formed from the third mesoblastic somite of the head. The seventh or facial nerve is formed of fibres which belong in all probability to the ventral gangliated group. It supplies muscles which are formed in the lateral mesoblast; it is connected with the geniculate ganglion and with the submaxillary ganglion; and Gaskell has discovered in its trunk, as in those of the third and the motor portion of the fifth, remains of ganglionic structure. The fibres of the eighth or auditory nerve correspond to those of the dorsal gangliated group which are specially connected with the epiblast, and its ganglia correspond to an afferent ganglion. The ninth, or glosso-pharyngeal, and the tenth, or vagus, may be taken together; each consists of two portions, one corresponding to the dorsal group and the other to the ventral gangliated group. The two ganglia of each nerve may possibly represent the afferent and the efferent ganglia of a typical segmental nerve-trunk. The eleventh, or spinal accessory nerve, is made up of two portions, one of which, the accessory portion, is probably to be regarded as a portion of the vagus trunk, the other, the spinal portion, as a set of fibres belonging to the anterior roots of the cervical segmental nerves. The twelfth, or hypoglossal, is usually regarded on account of its superficial origin and central connections as comparable to the ventral non-gangliated portion of the root of a segmental nerve, but from their distribution the glossal fibres would seem to belong more naturally to the ventral gangliated group. It is interesting to notice that Froriep has discovered in the embryo a small ganglion associated with the hypoglossal trunk. If the foregoing conceptions of the arrangement and distribution of the cranial nerves are true, it follows that no cranial nerve in the adult has all the parts represented in a typical segmental nerve, namely, three groups of fibres, a dorsal afferent gangliated, a ventral efferent gangliated, and a ventral efferent non-gangliated. The

fourth, the sixth, and, according to most, the twelfth trunk seem to be formed purely of fibres belonging to the ventral non-gangliated group. The motor of the fifth and the seventh seem to be formed of fibres belonging entirely to the ventral gangliated group. The sensory of the fifth and the eighth nerve would be formed purely of fibres belonging to the dorsal gangliated group. Of mixed trunks the third nerve seems to be formed of fibres belonging to the ventral non-gangliated and the ventral gangliated efferent groups; while the ninth and tenth would be made up of fibres belonging to the dorsal afferent and the ventral efferent gangliated groups.

THE CEREBRO-SPINAL AXIS AND ITS MEMBRANES.

Cerebro-spinal axis is the name given to the whole of the great continuous centre of the cerebro-spinal nervous system. Though obviously consisting of two parts, the brain and the spinal cord, and though the cord is comparatively simple in structure and similar in appearance in different parts of its length, while the brain is so complex and so dissimilar in its successive parts as to be even now incapable of being fully compared with the cord in its details, yet the cerebro-spinal axis is single in its origin, and indivisible in the adult condition save by arbitrary section.

FIG. 416.—CEREBRO-SPINAL AXIS.

It is a symmetrical organ, and the nerves arise from it in pairs, both the cerebral nerves, as those are called which come from the brain, and the spinal nerves, or those belonging to the cord. The brain or encephalon occupies the cranial cavity, and fills it, as it does also in all birds and mammals; but the spinal cord is far from filling up either the length or the width of the spinal canal in which it lies, and floats in a watery *cerebro-spinal fluid*. Both brain and spinal cord are surrounded by three coverings called meninges, namely, the *dura mater*, the *arachnoid*, and the *pia mater*.

The dura mater is a tough fibrous membrane, the deep surface of which is smooth and free,[1] coated with fine endothelium, and lies in contact, for

[1] This description is given in deference to the prevalent fashion. Nevertheless it is the case that, at least in the foetus, there is a layer which is easily filled in patches with injection, exhibiting a close network of vessels, with a delicate transparent layer over them, and uninjected fibrous tissue beneath. This I have seen

the most part continuously, with the opposed free surface of the arachnoid, which has likewise an endothelium. The space between dura mater and arachnoid, formerly known as the *arachnoid space*, is now usually termed *subdural*. The dura mater of the cord forms a loose sheath, which extends some way into the sacrum. It is separated by loose connective and adipose tissue, as well as by veins, from the periosteal and ligamentous walls of the canal, but is kept in position by bands of fibres which pass downwards from its anterior surface to be attached to the posterior common ligament over the bodies of lumbar and sacral vertebrae. The anterior and posterior roots of the spinal nerves pierce it near the intervertebral foramina by which they respectively emerge, and its fibres are continued on them and mingle with their bundles; but on its deep side the anterior and posterior roots of each nerve disappear by two openings, separated one from the other by a fibrous band.

The dura mater within the cranium differs from that in the spinal canal in being adherent to the bone, and performing at once the offices of fibrous covering to the brain and of periosteum to the inner table of the skull. It sends inwards three septa—the tentorium cerebelli, the falx cerebri and the falx cerebelli.

The *tentorium cerebelli* is projected between the cerebellum and the posterior lobes of the cerebral hemispheres. Its attachment extends from

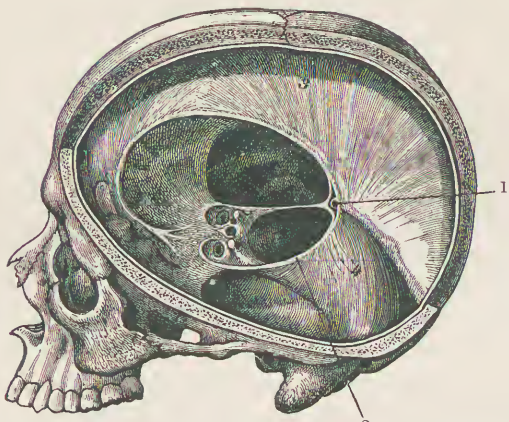


FIG. 417.—TENTORIUM CEREBELLI AND FALX CEREBRI. 1, Entrance of great vein of Galen into the straight sinus; 2, free margin of tentorium: 3, falx cerebri; 4, left side of tentorium. (Luschka.)

the internal occipital protuberance, along by the groove for the lateral sinus, and thence by the posterior and upper border of the petrous part

both in the spinal part and on the sides of the falx cerebri. It is also to be remembered that it has long been recognised that in the neighbourhood of the base of the falx very small accumulations of delicate tissue can be seen beneath the deep surface. These circumstances, together with the early condition found by me in cases of complete open spinal bifida (*Jour. Anat. and Phys.*, 1883), favour the old view that a parietal arachnoid adheres to the dura mater.

of the temporal bone, with the superior petrosal sinus in the groove along its line of attachment, and stretches from the tip of the petrous to the tip of the anterior clinoid process. Its free margin is of a horse-shoe form, reaching from one anterior clinoid process to the other, including in its curve a space through which passes a constricted part of the brain, termed *isthmus cerebri*; and its surface is arched, being most elevated in the middle of its free edge. The *falx cerebri* is a mesial septum named from being sickle-shaped. It is attached to the crista galli of the ethmoid, and along by the whole length of the groove marking the course of the superior longitudinal sinus, and to the tentorium cerebelli forwards as far as the free margin of the latter. The free margin of the falx cerebri is not always very definite throughout; and running in connection with it there is a small venous channel, the inferior longitudinal sinus. This and a trunk formed by the *veins of Galen*, enter from the interior of the brain at the junction of the margins of the falx cerebri and tentorium, while the straight sinus is hollowed out in the line of contact of these two septa.[1] The *falx cerebelli* is a slight mesial projection of dura mater beneath the tentorium, and in its line of attachment the occipital sinus is placed.

The arachnoid is a thin transparent membrane which loosely invests the cerebro-spinal axis, superficial to the pia mater, resting on it in many places and connected with it by loose tissue, while in others it is completely separated by a considerable distance; the whole interval, both where fibres are absent and where they are present, constituting the *subarachnoid* space. The arachnoid is a water-tight membrane, presenting to the subdural space a smooth surface covered with endothelium, and consists mainly of laminated straight white fibres, which near the surface are stretched out in a sheet without perforation, but more deeply form trabeculae. Immediately under the endothelium, and also more deeply, there is also homogeneous membrane, alleged to be composed of flattened cells. Large oval nuclei, like those of synovial membranes, are abundant in the trabeculated part, and leucocytes occur in great numbers in the meshes.

In the spinal canal the arachnoid surrounds not only the spinal cord, but the collection of roots of nerves proceeding downwards from it called *cauda equina*, enveloping it in one large loose sheath, which extends down to the extremity of the tube of dura mater; and it is within this extensive part of the subarachnoid space, together with its continuation upwards on the spinal cord, that the *cerebro-spinal fluid* is principally situated, while the surfaces of the subdural space are more closely in contact,

[1] Bearing on the irregularity of the free margin of the falx, I have made the observation that in the foetus the falx extends down to the corpus callosum, and is inferiorly quite continuous with the arachnoid, and that before birth the lower part begins to disappear, leaving the fold of arachnoid from one hemisphere to the other free or nearly so.

resembling in this respect other opposed endothelial surfaces. On each side the arachnoid has a series of attachments to the dura mater of two sorts: it embraces the roots of each spinal nerve where they pierce the dura mater, and between the successive roots of nerves it surrounds the attachments of the ligamentum denticulatum to be hereafter described.

Within the cranium the arachnoid passes smoothly over the convolutions of the cerebral hemispheres and the laminae of the cerebellum, being loosely attached to the pia mater, but not dipping into the sulci. Between the hemispheres it reaches so far down as barely to touch the pia mater of the corpus callosum; and from the hinder end of that structure it passes directly to the upper surface of the cerebellum. There are two spots (*cisternae*) at which it is removed a considerable distance from the pia mater—one below the cerebellum, where it passes directly down behind the fourth ventricle to the lower part of the medulla oblongata; the other at the base of the brain, stretching over the rhomboid space between and in front of the crura cerebri, and extending laterally to the Sylvian fissure, and between each crus and the overlapping hemisphere. The arachnoid within the cranium is in continuity with the dura mater where the different cranial nerves leave the subdural space, also where the veins quit the pia mater and stretch across to the superior longitudinal cavernous and other sinuses.

The Pacchionian bodies (described by Pacchioni, 1721) are round semi-transparent structures, irregular in number and situation, but principally occurring near the mesial plane, beneath the roof of the skull, and almost constantly present in the adult; some of them generally pushing their way partially through the dura mater and causing absorption of the inner table of the skull, while others may find their way through the wall of the superior longitudinal sinus. They were shown by Luschka (1852) to be clavate enlargements of villi of the arachnoid, and they may be fairly compared, like the grapelike growths of the nucleus pulposus of an intervertebral disc, with villi of synovial membranes. They do not all arise from the surface to which latterly the term arachnoid has been restricted. Luschka, like anatomists of the time when he wrote, looked on the deep surface of the dura mater as covered with a parietal arachnoid, and he carefully described parietal as well as other Pacchionian bodies. I had occasion to confirm his observations (1863). Though acknowledged to be coated with endothelium, Pacchionian bodies often form adhesions which mask the pedicle.

The pia mater is the vascular covering of the cerebro-spinal axis. Only very small bloodvessels are admitted within the nerve-substance of the brain and cord; the largest veins showing in sections of the brain as mere dark spots, while the arteries are still smaller. The arteries, after piercing the dura mater, pass into the pia mater and branch out into large numbers of small twigs, from which smaller arterioles plunge vertically into the brain-substance; and in like manner the emerging

venous radicles are gathered together in the pia mater into large trunks. The pia mater consists of these arteries and veins, together with a small amount of white fibrous tissue, partly in the form of bands with elastic fibres wound round them. It adheres closely to the surface of the nerve-substance, being folded in so as to be applied to the walls of the anterior longitudinal fissure of the cord and of the sulci of the cerebral hemispheres and the cerebellum, and mingles with every nerve-root. It also dips into the interior of the brain at two places, namely, the transverse fissure and the fourth ventricle, forming vascular fringes, called *choroid plexuses*, to be described with the details of the brain.

The *pia mater of the spinal cord* has its fibrous tissue strengthened at certain places to form longitudinal bands. One of these is a shining thread in the middle line in front (*linea splendens*); another, broader, called *ligamentum denticulatum*, runs down on each side between the anterior and posterior roots of nerves, and gets its name from being attached to the dura mater between the roots of each nerve and those of the nerve below by a slender but firm thread clothed with the arachnoid, which is thus thrown into a denticulated line. There are about twenty-one such denticulations—the first placed above the sub-occipital nerve and in front of the vertebral artery; the last about the level of the first lumbar vertebra. Inferiorly the fibres of both ligamentum denticulatum and linea splendens are continued into a thread called *filum terminale*, extending downwards from the extremity of the cord. In the middle line, behind the cord, a network of trabeculae, partly single, partly double, extends from between the posterior nerve-roots of opposite sides, across the subarachnoid space, back to the arachnoid membrane, and is described as the *septum posticum* of the subarachnoid space.

THE SPINAL CORD.

The spinal cord (*medulla spinalis*) is continuous above with the part of the brain called *medulla oblongata*, which passes into it without any line of separation. It extends very constantly from the foramen magnum to the lower border of the body of the first lumbar vertebra, varying usually between 16 and 18 inches in actual length. It is of generally cylindrical form, but with differences of size and shape at different levels. It is circular in section in the greater part of the thoracic region, and $\frac{3}{8}$th inch or more in diameter, while it is of slightly greater transverse breadth at its commencement. But it has two enlargements—the cervical and the lumbar. The *cervical enlargement* extends from near the commencement, as far as the emergence of the first thoracic nerve, and is characterized by increase in transverse breadth. It is the part which furnishes the roots of the nerves from which the large trunks (brachial plexus) for the supply of the upper limb arise. The *lumbar enlargement* is less noticeable, being caused by expansion all round, but to

less extent in any one diameter. It begins more than two inches above the lower end, and tapers inferiorly into a conical extremity, in which

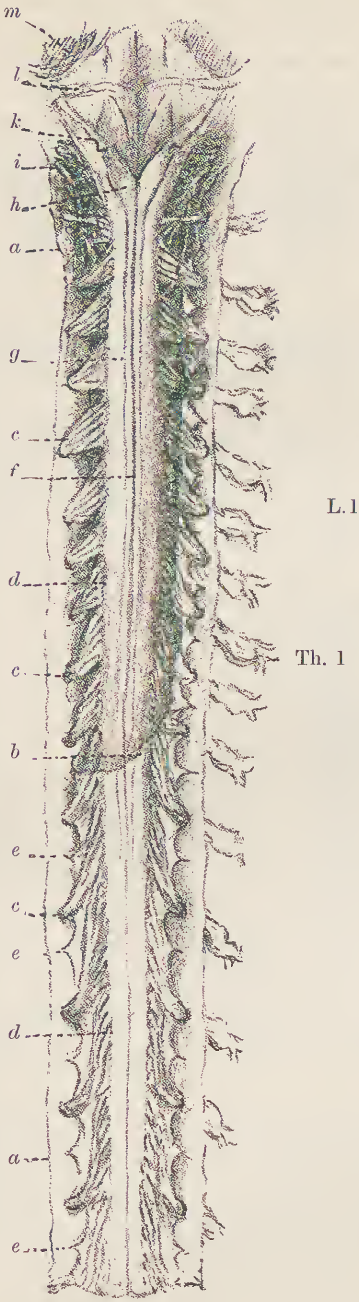


FIG. 417.

FIG. 418.—MEDULLA OBLONGATA, AND THE SPINAL CORD DOWN TO 8TH THORACIC PAIR OF NERVES, from behind. The range of spinal ganglia of the right side is seen beyond the divided dura mater. *a*, *a*, Other edge of divided dura mater; *b*, edge of arachnoid, below which the sub-arachnoid space is unopened; *c*, *c*, posterior roots leaving the subdural space; *d*, *d*, line of posterior roots emerging from spinal cord; *e*, *e*, *e*, attachments of ligamentum denticulatum; *f*, posterior fissure; *g*, groove between columns of Burdach and Goll; *h*, clava; *i*, spinal accessory nerve; *k*, ligula; *l*, striae acusticae; *m*, divided crura cerebelli.

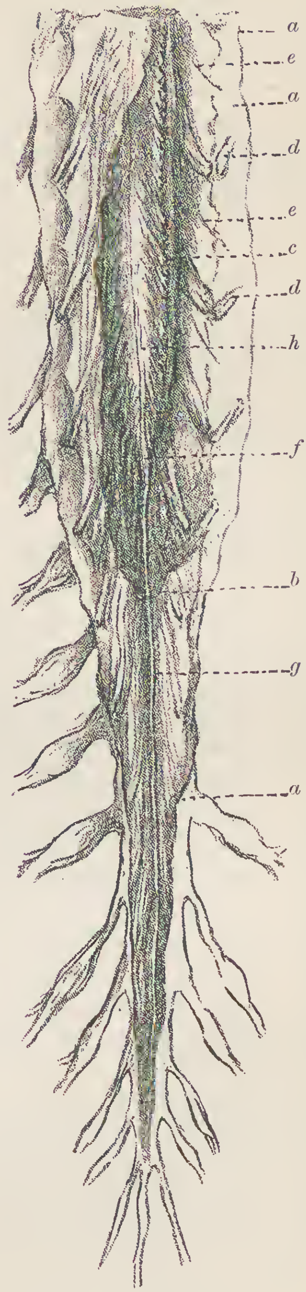


FIG. 418.

FIG. 419.—LOWER PART OF SPINAL CORD AND MEMBRANES, from before. *a*, *a*, *a*, Edge of dura mater; *b*, edge of arachnoid; *c*, line of divided anterior nerve-roots; *d*, *d*, distal ends of divided anterior nerve-roots; *e*, threads of ligamentum denticulatum stripped of their arachnoid covering; *f*, extremity of spinal cord; *g*, filum terminale lifted out from the nerve-roots of the cauda equina and seen through the arachnoid; *h*, linea splendens.

the cord terminates. Both this enlargement and the sides of the conically-tapering extremity afford origin to closely-crowded roots of lumbar and sacral nerves, including those which supply the lower limbs. These roots of nerves, from above downwards, extend for regularly-increasing distances within the dura mater to reach the successive intervertebral foramina, and the whole bundle of them lying beyond the cord, within a loose sheath of arachnoid, is called the *cauda equina.* Hid in the centre of the cauda equina is the silvery thread, *filum terminale*, continuous with the pia mater, which stretches down to the extremity of the dura mater, to be fixed with it to the lower end of the sacrum.

In the mesial plane the cord exhibits in its whole length, continued down from the medulla oblongata, a deep *anterior fissure* into which a mesial process of pia mater dips, and posteriorly a depressed line, descending from the calamus scriptorius of the medulla oblongata, indicating the edge of a *posterior fissure* closed in its whole length by a reticulum of supporting material proper to the cord, the *posterior septum.*

On each side the roots of the spinal nerves are connected with the cord in two series—the *anterior roots* (also called *motor*) distributed to the voluntary muscles; and the *posterior roots* (or *sensory*), distributed to the integument. Each root, whether anterior or posterior, consists of separate bundles, and, save in the upper part of the neck, the nearest bundles of successive roots are not further separate than the successive bundles of one root; but the bundles of each root approach one another as they pass outwards, the lowest bundles of the uppermost roots being horizontal, and those of succeeding roots more and more directed downwards. The bundles of the anterior roots lie four or more abreast, the innermost emerging gently from the cord and concealing those external to them; and there is no depression where they appear, the *antero-lateral furrow*, sometimes described, having no existence in nature. The bundles of the posterior roots, on the contrary, lie in a single longitudinal series, standing out abruptly in a distinct *postero-lateral* furrow further removed from the middle line than the inner bundles of the anterior roots. Each posterior root, after emerging from the dura mater, has a *spinal ganglion* placed on it before being joined by the anterior root to form the nerve-trunk; and the spinal ganglia are so intimately connected with the microscopic structure of the cord itself that neither can be understood apart from the other.

Internal structure. On transverse section of the cord the posterior septum is seen to be deeper than the anterior fissure, and the distance between the two is not more than an eighth of the antero-posterior diameter on each side. At the bottom of the anterior fissure, white substance, consisting of fibres crossing the mesial plane, constitutes the *anterior* or *white commissure*, and the rest of the distance back to the posterior septum is occupied by the *grey commissure*, in the middle of which, dividing it into *anterior* and *posterior grey commissure*, there is a small canal, the *central canal*

of the spinal cord. The canal is invisible to the naked eye in the unprepared human subject, and just visible in hardened sections; but is a structure of much morphological significance, inasmuch as the spinal cord in its earliest embryonic condition was a grooved superficial ribbon whose sides were folded backwards so as to complete a tube which persists in this form,

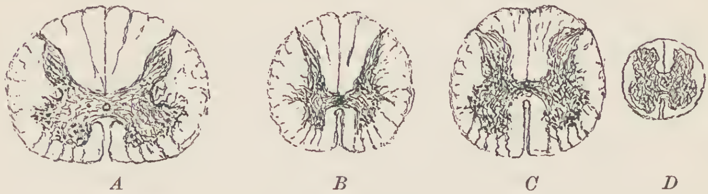


FIG. 420.—SECTIONS OF SPINAL CORD. *A*, Mid-cervical; *B*, mid-thoracic; *C*, mid-lumbar; *D*, near the pointed extremity. Below, in the middle of each, is the open anterior fissure; above is seen the posterior fissure, and on each side of it, in *A* and *B*, a septum which lies between the columns of Burdach and Goll.

and of whose walls the spinal cord is the developed condition. The central canal is continued above into the medulla oblongata to open into the calamus scriptorius, the mesial groove of the floor of the fourth ventricle; and it is prolonged down a long way into the filum terminale, which is thus, at least in its upper part, a continuation of the cord without develop-

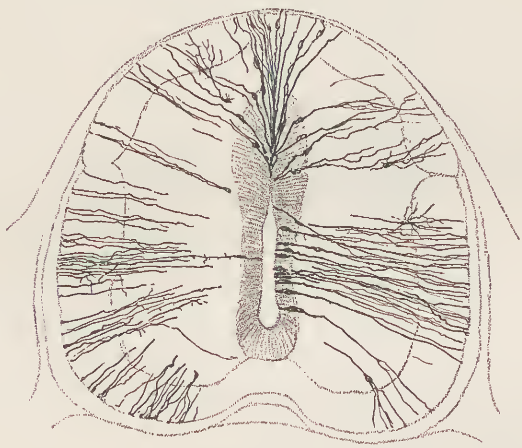


FIG. 421.—EPENDYMAL OR SPONGIOBLASTIC FIBRES OF THE CORD OF A SEVEN DAYS' CHICK. Golgi method. (v. Kölliker.)

ment of nervous elements. The central canal is lined with elongated columnar ciliated epithelium, whose cells exhibit by the Golgi method a continuity with spongioblastic or neuroglial elements. The grey commissure is prolonged on each side into an expanded mass of grey matter, prolonged forwards and backwards so as to form what are called the *anterior* and *posterior cornua*, the anterior cornu clavately expanded and giving off the anterior roots of nerves, while the posterior cornu is con-

tinuous with the posterior roots. The whole surrounding texture consists of white substance.

The **white substance** is arranged in three columns, anterior, lateral and posterior; the *lateral column* consisting of as much as lies between the anterior and posterior roots, and having the anterior and posterior columns respectively in front and behind it. The *posterior column* is perfectly separate, being situated internal to the posterior cornu; but in consequence of the bundles of the anterior roots being transversely scattered, the *anterior column* is not so definitely distinguished from the lateral column, and therefore it often becomes necessary to speak of the two together as the *antero-lateral column.* When the anterior and lateral columns are spoken of separately, the outermost bundles of the anterior are taken as marking their plane of separation. Save at the white commissure, the white substance consists of longitudinally directed medullary nerve-fibres closely packed in supporting substance. Fibres of different diameters are intermingled; but those of largest size are most abundant toward the circumference of the antero-lateral column. A number of imperfect longitudinal septa, similar in substance to the posterior septum, extend from a superficial circumferent layer of neuroglia inwards through the white substance, breaking up and disappearing at different distances from the surface. It is principally in these septa that the arterioles pass inwards, giving off a sparse capillary network to the white matter, and ending in a more copious network in the grey matter; but a pair of longitudinal vessels formed by anastomosis of branches of the anterior spinal artery run in the grey commissure, one on each side. The septa are continuous with substance between the nerve-fibres, and contain, as well as it, neuroglia-corpuscles with large numbers of threadlike branches. No such septa are found above the medulla oblongata.

Tracts in the white substance are recognised, not indeed in most instances to be distinguished one from another in sections, but having different connections, as evidenced by degenerations following lesions, according to Waller's law (p. 53), or by aid of the fact that in development different strands receive their medullary sheaths at different periods (Flechsig's method), or by direct anatomical observation, especially in early development. They are termed ascending or descending according as experiment or other evidence shows that their fibres run upwards or downwards from the corpuscles from which they start.

In the anterior column, on each side of the anterior fissure, is a descending tract, the *direct pyramidal* tract, or *column of Türck*, continued down from the outer fibres of the anterior pyramid of the medulla oblongata, and diminishing steadily from above downwards. The remaining larger part of the anterior column, the *anterior ground part*, appears to consist of mixed ascending and descending fibres, emerging from the grey substance and re-entering it after short courses.

In the lateral column there are distinguished three cerebellar tracts on the surface. The largest known is the hindermost; it is the *direct*

ascending cerebellar tract, and was pointed out by Flechsig. In front of it is the *indirect ascending cerebellar* tract, or tract of *Gowers*, whose fibres pass up into the pons before reaching the cerebellum by the superior peduncle; and still further forwards is the *descending cerebellar* tract, tract of *Lowenthal* or *Marchi*, whose fibres undergo degeneration from above downwards after removal of the cerebellum. Beneath the direct ascending cerebellar tract there runs the important *crossed pyramidal tract*, continuous with the inner or decussating fibres of the anterior pyramid of the medulla oblongata. Still deeper, between the anterior and posterior cornua, is the *lateral ground part*, consisting of fine fibres in bundles separated by grey reticulations, and taking very short courses outside the grey substance. Lastly, at the back of the lateral column, and invading the posterior column, there is a group of fine fibres, the *marginal tract of Lissauer*, connected with the posterior nerve-roots.

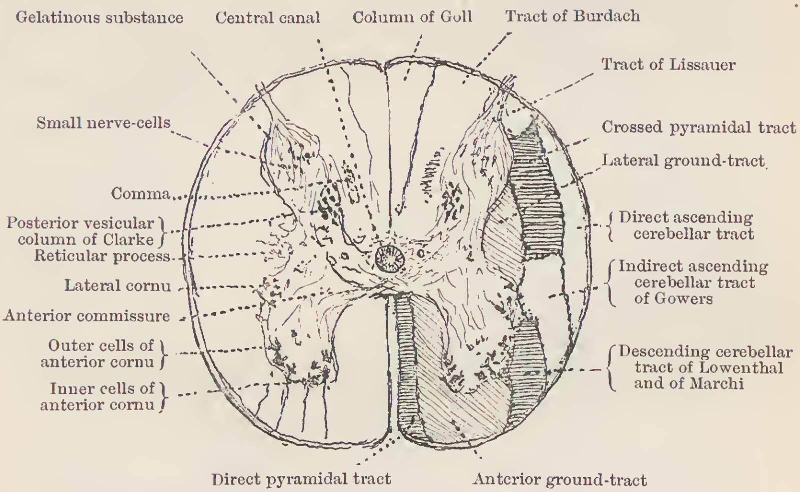


FIG. 422.—DIAGRAMMATIC TRANSVERSE SECTION OF CORD IN LOWER DORSAL REGION. On one side the ascending tracts are left white, the descending tracts marked with horizontal lines, and mixed fibres marked with oblique lines.

In the posterior column a longitudinal septum, continued down from the furrow between clava and cuneate fasciculus in the medulla oblongata, separates, to a certain extent, an inner portion, *the column of Goll*, from the larger outer part or tract of Burdach. Both of these columns are partly continuous with the posterior nerve-roots, but in neither do the root-fibres continue for more than a limited extent. The only fibres of the posterior column known to undergo descending degeneration after injury to the cord are deeply placed on the inner side of the posterior cornu, and are known as the *comma*. Further observation, however, appears necessary before they can be identified with the descending divisions of the bifurcating fibres of the posterior nerve-roots described below.

The **grey substance** of the cord varies in amount at different levels.

It is most developed in the cervical and lumbar enlargements, and smallest below the middle of the thoracic region, where both anterior and posterior cornu are very narrow, while in the conus medullaris the white matter disappears more rapidly than the grey, leaving a ring of unsurrounded grey matter at the upper end of the filum terminale.

The *anterior cornu* has an outline running from its foremost part in a direction outwards and backwards; and more or less continuous

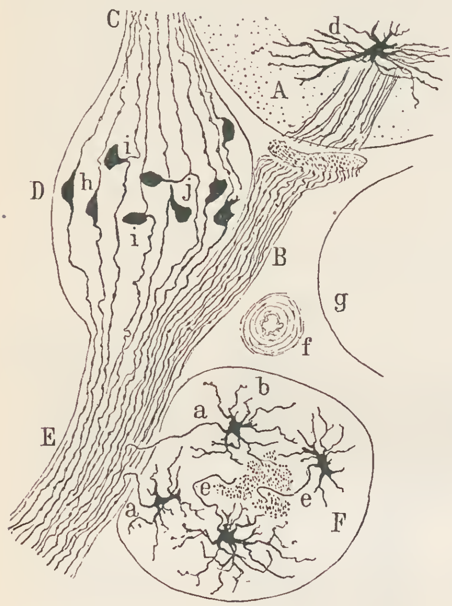


Fig. 423.

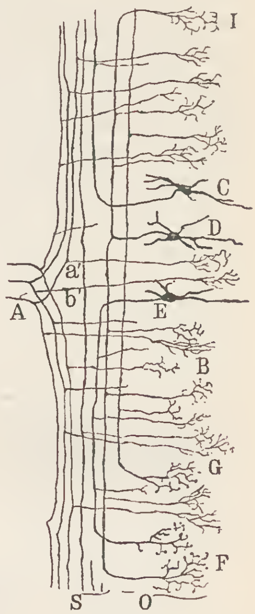


Fig. 424.

Fig. 423.—Spinal and Sympathetic Ganglia from Neck of Chick of 17th Day. A, Spinal cord; B, anterior root; C, posterior root; D, spinal ganglion; E, spinal nerve; F, sympathetic ganglion. *a*, *a*, Sympathetic axis-cylinders of the communicating branches directed to the spinal nerve; *b*, protoplasmic branches of sympathetic nerve-corpuscles; *d*, nerve-corpuscle of anterior or motor-root; *e*, *e*, sympathetic axis-cylinders becoming vertical; *f*, artery cut across; *g*, body of vertebra; *h*, fusiform corpuscle of spinal ganglion; *i*, *i*, transition from bipolar to unipolar corpuscle; *j*, completely unipolar corpuscle. (Cajal.)

Fig. 424.—Semi-Diagrammatic Longitudinal Section of Posterior Column, parallel to Posterior Roots. S, White substance; O, grey substance; A, posterior root; *a'*, collateral from its ascending branch; *b'*, collateral from its stem; B, collateral from its inferior branch ending in arborization (above the letter); C, corpuscle with axis-cylinder which turns upwards in the white substance; D, corpuscle with bifurcating axis-cylinder; E, corpuscle with axis-cylinder turned downwards; F, G, arborizations of axis-cylinders. (Cajal.)

with this outward extension, but most distinct from it in the region supplying the thoracic nerves, there is a projection which has been called the *lateral horn* (intermedio-lateral tract of Lockhart Clarke); while in the concavity between this and the posterior cornu the grey matter has a particular tendency to form a reticulation round longitudinal white bundles, the *reticular process.* The anterior cornu has the most abundant cells, and those which appear the largest in transverse sections of the cord; they are multipolar, and have their axis-cylinder-processes con-

tinued into anterior roots of nerves. They are arranged in groups, especially toward the extremity of the cornu, and those of the lateral cornu form a similar group adjacent to them.

The *posterior cornu*, less swollen and, save in the lumbar enlargement, more elongated than the anterior, is less marked by nerve-cells. It presents in transverse section a slight bulbous swelling, supported by a neck, and extending to the postero-lateral groove, where it receives the posterior nerve-roots. Toward the tip it presents in the fresh state a semi-transparent portion, the *substantia gelatinosa of Rolando*, in which there is a transverse band of very small roundish corpuscles. The other nerve-corpuscles of the posterior cornu are mostly toward its margins, and are sparse, larger than those of the substantia gelatinosa, though much smaller than those of the anterior cornu. But along with the posterior cornu there is to be noticed a very definite collection of nerve-corpuscles, the *posterior vesicular column of Lockhart Clarke*, lying close to the inner side of its neck, with fine fibres curving round it. This column is almost confined to the region of the cord connected with the thoracic roots. Its cells are multipolar, normally smaller in transverse section than those of the anterior cornu, but considerably longer vertically. Flechsig pointed it out as the source of the direct ascending cerebellar tract, and Cajal has traced some of its axis-cylinders into that part of the lateral column, while he has followed others into the anterior commissure. Gaskell considers it as probably the source of the splanchnic efferent nerves.

FIG. 425.—ASCENDING DEGENERATION IN POSTERIOR COLUMN OF SPINAL CORD IN DOGS, after division of posterior nerve-roots. I. After division, by Singer, from 2nd sacral to 6th lumbar: *a*, at level of 6th lumbar; *b*, of 3rd thoracic; *c*. of middle of neck. II. After division, by Singer, of 11th and 12th thoracic: *a*, at level of 12th thoracic; *b*, of 3rd thoracic; *c*, of middle of the neck. III. After division, by Kahler, from 5th cervical to 2nd thoracic: *a*, at level of 1st thoracic; *b*, of 6th cervical; *c*, of 1st cervical. (Toldt.)

The **nerve-roots.** The *anterior nerve-roots* consist of fibres mostly, if not all of them, from the axis-cylinders of the multipolar corpuscles of

the anterior cornu of the same side, and devoid of collaterals. It is open to question if any can be traced to the opposite side, or if the fibres of the white commissure are not rather derived from special corpuscles in the anterior cornu, and continued into the antero-lateral cord of the other side. Such commissural fibres have been seen, after crossing, to divide into an ascending and a descending fibre.

The *posterior nerve-roots* contain some centrifugal fibres from the anterior cornu (Lenhossek and Cajal), but consist principally of centripetal fibres from the spinal ganglion. The nerve-corpuscles of these

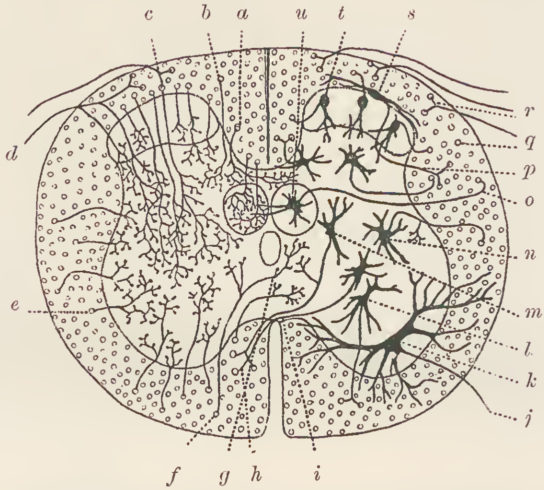


FIG. 426.—DIAGRAM OF RELATIONS OF DIFFERENT ELEMENTS. *a*, Collaterals from column of Goll, forming larger part of posterior commissure; *b*, collaterals from column of Goll to posterior cornu; *c*, collaterals, some of which reach forward to the anterior cornu; *d*, posterior nerve-root and its collaterals; *e*, collaterals from antero-lateral column to anterior cornu; *f*, *g*, collaterals crossing in anterior commissure; *h*, axis-cylinder arising from corpuscle in anterior cornu, and crossing to anterior column of opposite side by anterior commissure at *i*; *j*, motor nerve-root arising from motor corpuscle *k*; *l*, bifurcating axis-cylinder of anterior column arising from corpuscle of same side; *m*, another arising from opposite side; *n*, corpuscle with axis-cylinder giving off collateral in the grey substance; *o*, axis-cylinder from column of Clarke; *p*, axis-cylinder from *s*; *q*, transverse section of axis-cylinder; *r*, bifurcation of posterior nerve-root; *s*, marginal corpuscle of substance of Rolando; *t*, small corpuscle of the same; *u*, corpuscle of Clarke's column. (Cajal.)

ganglia are unipolar in the adult condition (p. 51), but the one pole divides into a centrifugal and a centripetal branch; and within the cord the centripetal branch is found to bifurcate into an ascending and a descending fibre, both ending by arborization in the posterior cornu. As the fibres enter the cord they are distinguishable, according to Cajal, into an outer and an inner fasciculus, the outer consisting of fine fibres bifurcating in the marginal zone of Lissauer, and ending wholly in the posterior cornu, the internal consisting of larger fibres which bifurcate in the columns of Goll and Burdach.

Sections, in living animals, of posterior roots before entering the cord show that the continuations upwards of their fibres, after ascending a

certain distance, quit the white substance, and in their course they are pushed toward the mesial plane by others entering above them (Fig. 425).

The **collaterals** given off from axis-cylinders in the white substance add to the structure of the spinal cord a remarkable complication, our knowledge of which is due to Golgi's methods and dates no earlier than from 1880. These delicate fibres are given off at right angles from axis-cylinders, and pass horizontally into the grey substance to end in arborizations. They arise very abundantly from the posterior columns, springing there in greater number from fibres of posterior roots. Of these one important group extends directly forwards into the anterior cornu, and

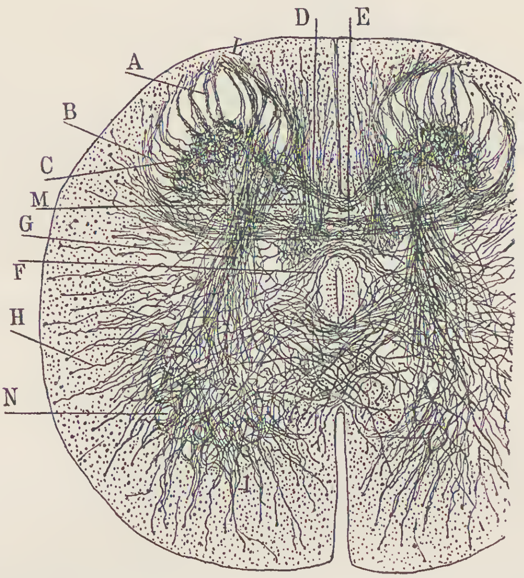


FIG. 427.—SECTION OF SPINAL CORD OF DOG AT BIRTH, SHOWING DISPOSITION OF COLLATERALS. A, Bundles crossing the substance of Rolando; B, bundles crossing from outer side of cornu to opposite side; C, dense plexus; D, from posterior column to posterior cornu of opposite side; E, F, middle and anterior bundles in grey commissure; O, sensivito-motor bundles; H, I, from anterior and lateral columns; L, point of origin of numbers of sensitivo-motor bundles; M, fasciculus going to Clarke's column; N, situation of anterior corpuscles. (Cajal.)

surrounds with its arborizations the corpuscles of the motor nerve-roots, constituting the *sensitivo-motor* or *reflexo-motor fibres,* and furnishing an explanation of reflex actions. Others form a dense plexus in front of the substance of Rolando. A third set crosses the middle line, many of its fibres springing from the column of Goll; while a fourth small set, coming from the column of Goll, ends by embracing the corpuscles of the posterior reticular column of Lockhart Clarke. A number of the collaterals springing from the antero-lateral columns cross the middle line, those of the anterior column passing in front of the central canal, and those of the lateral columns passing behind it.

The researches of Brown-Sequard first showed that sensory impressions

were conveyed from the hind limbs of animals after division of the posterior columns on both sides nearer the head, and that a mesial section of the cord made opposite the origins of the nerves to the fore limbs paralysed sensation in both those limbs without affecting the hind limbs. These observations, as also more recent researches of Edinger and the disposition of the collaterals, all point to a decussation of sensory tracts in a forward direction, and not far from the entrance of the posterior nerve-roots, in the length of the cord.

THE BRAIN.

I. GENERAL CONSTRUCTION.

The brain, or *encephalon*, presents below, resting on the basilar process of the occipital bone, a short extension upwards from the spinal cord, namely, the *medulla oblongata*, increasing in breadth, and rapidly changing both in the disposition of its parts and the mode of origin of nerve-roots. The medulla oblongata is crossed superiorly by the *pons Varolii*, a body having the appearance of a great band of transverse fibres, forming a prominence, which rests on the upper part of the clivus as far as the summit of the dorsum sellae, and is gathered together at each side to enter the *cerebellum.* The cerebellum is a large brain-mass presenting a laminated surface of grey substance, and, together with the medulla oblongata and pons, fills the part of the cranial cavity beneath the tentorium. The whole of the rest of the brain, occupying all the cranial cavity above the tentorium, constitutes the *cerebrum.* The cerebrum is continuous with the parts below the tentorium by the part traversing the constricted aperture bounded by the dorsum sellae and the free margin of the tentorium and termed the *isthmus cerebri*, which would be divided by a section made close above the pons and the cerebellum. The parts of the cerebrum in contact with almost the whole wall of the cavity above the tentorium are the right and left *cerebral hemispheres*, much the largest masses of the brain, and presenting convoluted surfaces of grey substance. The body of the sphenoid, however, from the summit of the dorsum sellae forward to the united orbital wings, is not invaded by the hemispheres, and the cribriform plate of the ethmoid has the *olfactory lobes* immediately overlying it.

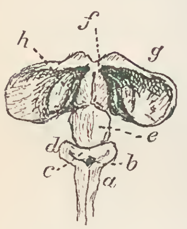


Fig. 428.—Brain of Human Embryo of 12 Weeks, with the pia mater removed, and the hemisphere spread out. *a*, Medulla oblongata; *b*, fourth ventricle; *c*, cerebellum; *d*, flocculus; *e*, corpora quadrigemina; *f*, optic thalamis; *g*, hemisphere-vesicle laid open; *h*, corpus striatum within it. (After Tiedemann.)

Emerging from the pons Varolii are two diverging pillars of white substance, the *crura cerebri*, speedily overlapped by the hemispheres; and, when followed round the side, the crura cerebri are seen to be in continuity dorsally with structures emerging from the cerebellum, invested

like them with pia mater; and the pia mater is also seen passing onwards into the interior of the cerebrum by what is called the *transverse fissure*, separating the root part of the cerebrum from the hemispheres above and on the sides.

If the student will now, at the commencement of the study of the brain, glance at one early stage of development, he will be aided in forming a general conception which will materially assist the comprehension of the adult structure. The medulla oblongata, pons Varolii and cerebellum are developed in the wall of one expansion of the cerebro-spinal cylinder,

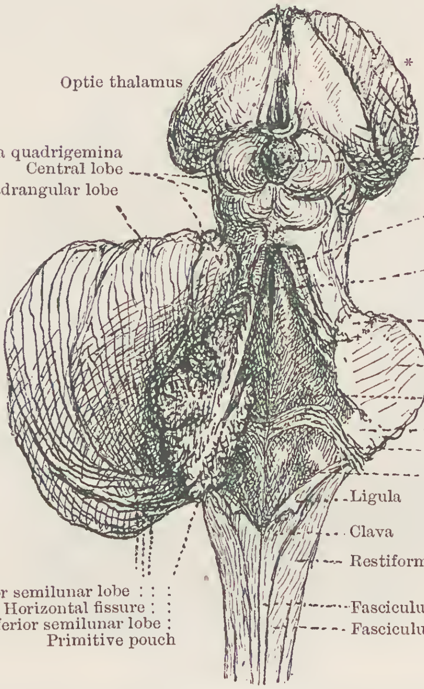


Fig. 429.—Dorsal View of Root of Brain, after removal of hemispheres by a cut at * separating the optic thalami from the corpora striata. The right half of the cerebellum is removed and the valve of Vieussens divided mesially to show the floor of the fourth ventricle.

namely, the third primary cerebral vesicle. They constitute the *metenecphalon*, (or *metencephalon* and *myelencephalon*), in the interior of which is left a dilated space, the *fourth ventricle*, continued up from the central canal of the spinal cord, but devoid of nervous wall in the part behind the upper half of the medulla oblongata. Above the metencephalon the nervous walls are again complete, and on the dorsum an elevation presenting a mesial and a transverse furrow, and on that account called *corpora quadrigemina*, is superimposed, while the canal is again constricted, and is called the *aqueduct of Sylvius*. This is the *mesencephalon*, derived from the second primary cerebral vesicle. Forwards from the mesencephalon there is another

expansion, the *thalamencephalon*, presenting dorsally a pair of bodies, the *optic thalami*, covered, like the corpora quadrigemina, with pia mater, and joined by a thin roof in the middle line, but with a larger space between them, and ultimately with the nervous roof thrown open. From the front of the thalamencephalon a pair of hollow outgrowths, also covered with pia mater, grow and expand so as to extend backwards and outwards and inwards over both optic thalami and corpora quadrigemina. These are the *hemisphere-vesicles*, their cavities are the future *lateral* ventricles, and they present each, projecting into the cavity from the floor close to the thalamencephalon, a solid part which constitutes the *corpus striatum*. At an early date the nervous walls of the hemisphere-vesicles become grooved and

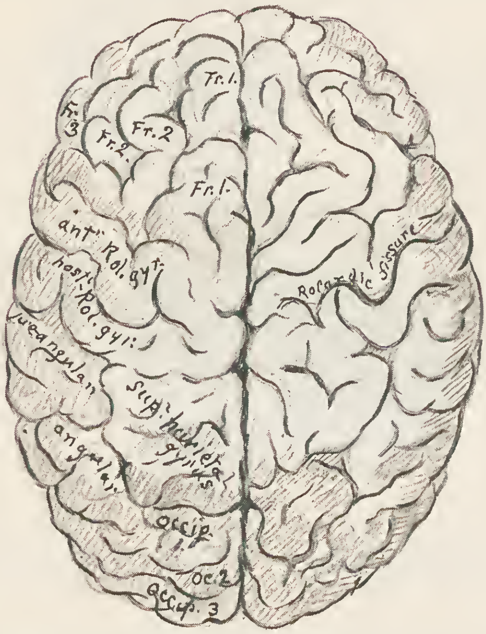


Fig. 430.—Brain from above, showing the two hemispheres. On the right the fissure of Rolando is marked, and on the left the principal convolutions.

imperfect close to the lines from which the roofs of the vesicles turn back over the optic thalami, and the pia mater at this part, reflected on itself, projects a hypervascular fringe, a *choroid plexus*, into the interior, extending from side to side of what is called the transverse fissure of the brain. Even in the adult, as pointed out by Reichert, a section can easily be made, dividing the optic thalami from the corpora striata, and passing closely in front of the optic tracts, and thereby separating the comparatively simple root of the brain from the hemisphere-vesicles, which owe their complexity to their magnitude, the convolution of their pia-matral surface, the formation of commissures crossing the mesial plane, and the unequal thickening of their walls.

Superior surface. The part of the brain in contact with the cranial vault is formed by the two hemispheres, separated by the *great longitudinal fissure*, into which the falx cerebri descends; and at the bottom of this fissure, in the extent corresponding with the free margin between the tentorial and ethmoidal attachments of the falx, the hemispheres are united one with the other by a great transverse commissure, the *corpus callosum.*

Inferior surface or base. The *medulla oblongata* is continuous with the spinal cord, and abruptly crossed at its other extremity by the *pons Varolii*, whose fibres gather together on each side and plunge into the *cerebellum.* The cerebellum spreads its lateral lobes on each side of the medulla oblongata and pons, and occupies the whole of the rest of the posterior fossa basis cranii behind them; it roofs over a space, the fourth ventricle, of which they form the floor.

The hemispheres extend backwards over the cerebellum and forwards to fill the frontal part of the cranium; and its projections in these directions are termed the *posterior* and *anterior lobes*, while a third projection of each hemisphere, distinguished as the *middle lobe*,[1] fills the middle fossa basis cranii external to the free edge of the tentorium, and is separated from the anterior lobe by the *fissure of Sylvius*, hidden within which there is a limited group of convolutions, the *gyri operti* or *Island of Reil*, the surface of the root-part of the hemisphere.

Emerging in mutual contact at the border of the pons, the *crura cerebri* diverge as they enter the optic thalami from below, and become concealed by the middle lobes of the hemispheres, while the transverse fissure of the brain, the middle part of which is placed above, between the corpus callosum and the corpora quadrigemina, enters on each side between the crus cerebri and the middle lobe. Crossing each crus, a white band, the *optic tract*, is directed forwards and inwards to the middle line, where it meets its neighbour and forms, in conjunction with it, the *optic commissure*, from which the optic nerves are continued. The optic nerves strike out free, being surrounded by a prolongation of the pia mater; but the optic tracts present only one free surface, and enter into the construction of the wall of the brain. A little external to the optic commissure, at the inner end of the Sylvian fissure, on each side, there is an area pierced by a large number of small arteries, the *anterior perforated spot.* Between the crura

[1] The expressions, anterior, posterior and middle lobe have been dismissed by some writers, but are still useful in their original sense as applied to projections in three different directions. The more modern expressions, frontal, parietal, occipital, temporal, orbital, central, limbic and falciform lobe, are neither applicable to projections nor to masses of the whole substance of the hemisphere, but properly refer to definite groups of convolutions. Professor Macalister has clearly and correctly stated the nature of these latter: "Certain infoldings are early and constant, and form important landmarks dividing the surface into areas called *lobes.* It must be borne in mind that these are only surface markings." Much confusion has resulted from neglect of this distinction. The anterior, middle and posterior lobes are *lobes of projection*; the groups of convolutions are *surface-lobes.*

and the optic tracts there is left a rhomboid space. In the posterior angle of this space, between the crura and in front of the pons, there is a depression where a number of small arteries, placed closely together, enter the cerebral substance, the *posterior perforated spot.* In front of this a pair of rounded white elevations like small peas lie together, the *corpora albicantia*, structures connected with the fornix; and in front of them the rhomboid space is filled by the *tuber cinereum*, a thin grey lamina whose deep surface looks into the third ventricle. The tuber cinereum is attached to the corpora albicantia, the inner edges of the optic tracts and the posterior edge of the optic commissure, and is prolonged into a hollow projection, *infundibulum*, which narrows rapidly, and is continuous by its slender extremity with the solid structure, *pituitary body*, occupying the sella turcica.

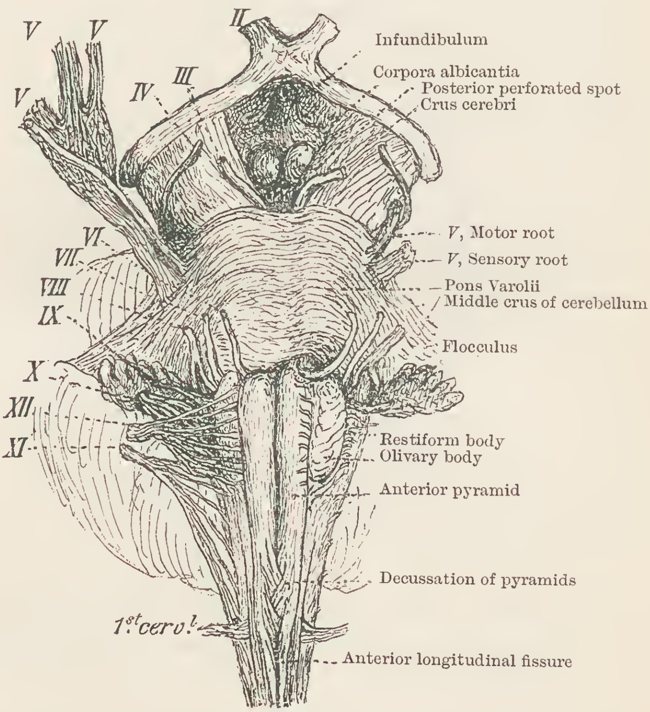


FIG. 431.—BASAL VIEW OF ROOT OF BRAIN after removal of hemispheres by a cut separating optic thalami from corpora striata, and passing along the anterior borders of the optic tracts. The lower border of the pons is slightly pressed upwards to show the descent of the fibres of the anterior pyramid and sixth nerve.

From the anterior border of the optic commissure there passes upwards another grey membrane, *lamina cinerea* (Fig. 446). When the anterior lobes of the hemispheres are separated from below, the fore part of the corpus callosum is brought into view, bending round from above, and prolonged back nearly as far as the front of the optic commissure, but at a higher level; and there it comes to an edge continued on each side into a *crus*

directed to the anterior perforated spot, while the lamina cinerea fills up the interval and forms the anterior wall of a cul-de-sac of the floor of the third ventricle, bounded below and behind by the optic commissure.

The optic nerves are, strictly speaking, portions of the brain, as are also parts of the contents of the eyeballs, both being derived from the primary optic vesicles of the embryo. In like manner, underneath the anterior lobes of the hemispheres, and resting on the cribriform plate of the ethmoid, there is a pair of structures, the *olfactory lobes*, each consisting of a narrow tract and broader bulb, formerly known as nerves, but now universally acknowledged to be lobes of the brain, giving off the olfactory nerves from the under surface of the bulbs (Fig. 453).

It may-be well also at this stage to indicate shortly the superficial origins of the other cranial nerves. They appear: the *oculo-motor* (3rd) on the inner side of the crus cerebri, just above the pons, and passing between the posterior cerebral and the superior cerebellar artery; the *nervus patheticus* (4th) on the outside of the crus, close to the pons, and below the superior cerebellar artery; the *trigeminal* (5th) from between the fibres of the pons, towards its outer extremity; the *abducens oculi* (6th), near the mesial plane, between the pons and what is called the anterior pyramid of the medulla oblongata; the *facial* and the *auditory* nerve, between the pons and the side of the medulla oblongata, in the angle between them and the cerebellum, the auditory to the outside; the *glosso-pharyngeal*, from the medulla oblongata just below the facial, in a furrow behind what will be described as the olivary body; the *vagus* or *pneumogastric* in the same furrow; the *spinal accessory* in a line continuous with the vagus; and the *hypoglossal* in the furrow internal to the olivary body.

II. THE MEDULLA OBLONGATA AND PONS VAROLII.

The **medulla oblongata** (*myelencephalon*) is about an inch long. Its ventral surface is bounded above by the lower border of the pons Varolii, and its dorsal surface is continued into the floor of the fourth ventricle. The anterior fissure of the spinal cord is continued up to the border of the pons, beneath which it has an abrupt end (*foramen caecum*); but about two-thirds of an inch lower down it becomes shallow for a third of an inch, and, when it is opened out, four or five bundles of white substance on each side are laid bare as they slope downwards and cross the mesial plane, decussating with their neighbours of the opposite side, and disappearing by dipping into the interior. This is the *decussation of the anterior pyramids*, already referred to in connection with the tracts of the spinal cord, and its lower border may be taken as the limit of the medulla oblongata. The *anterior pyramid* is an elongated elevation alongside of the middle line, becoming narrower and less prominent below; external to it is another elevation limited inferiorly, the *olivary body*; and external to the olivary body a thick rounded column, named *restiform* body on account of shallow

oblique marks giving it a ropelike appearance, passes upwards and outwards to enter the cerebellum, and forms the lateral wall and great part of the posterior wall of the medulla oblongata. Between the restiform bodies behind, lying together below, separated by the continuation of the posterior fissure of the spinal cord, are two slender columns, *funiculi graciles*, continuous with the columns of Goll. Superiorly the restiform bodies diverge, and the funiculi graciles between them first widen out so as to continue in contact one with the other, getting the name of *clavae* or *posterior pyramids*, then separate and taper each to a point still in contact with the restiform body, while between them is exposed the floor of the fourth ventricle.

So far as we have gone, the surface of the medulla oblongata is of white matter, and clothed with pia mater like the spinal cord; but here the parts behind the central canal fail any longer to meet, and grey matter, continuous with that of the spinal cord, is exposed; an open furrow, *calamus scriptorius*, being the consequence, continuous with the inlet to the central canal, between the clavae. Rudiments, however, of a posterior wall exist: namely, the *obex*, a minute ridge of white matter behind the orifice of the canal, and the *ligulae*, two attenuated bands attached internal to the clavae, and turned over like the lapels of a coat. The part of the medulla oblongata, in which the central canal is complete, is called the *closed part*, while that into whose construction the floor of the fourth ventricle enters is called the *open part*. The groove between the anterior pyramid and the olivary body dies away below, but is pretty much in a line with the anterior roots of the spinal nerves, and has lying in it a row of nerve-bundles, the root of the *hypoglossal nerve*. A group of *superficial arched fibres*, emerging from the anterior fissure, slope over the pyramid and the lower part of the olivary body, and join the restiform body. The groove between the olivary body and the restiform body is further forwards than the posterior roots of the spinal nerves, and in it is another row of nerve-bundles, forming the roots of three nerves; the few uppermost gathering together to form the *glosso-pharyngeal nerve*, a number of succeeding bundles becoming grouped in like manner to form the *vagus* or *pneumogastric nerve*, and the remainder, more sparsely scattered, the lowermost of them ascending between the anterior and posterior roots of several of the highest spinal nerves, all gathering together to make a third trunk, the *spinal accessory nerve*.

The **pons Varolii** is the structure which crosses the front and sides of the upper end of the medulla oblongata, and the name indicates a bridge extending from one half of the cerebellum to the other. But this bridge is too intimately connected with the prolongations of both white and grey matter from the medulla oblongata, and with the floor of the fourth ventricle, to be described separately from them, and thus the term pons Varolii has come to be extended to the whole depth of structure grasped on the front and sides by transverse fibres, and bounded by the fourth ventricle behind. It is broader in the human subject than in other mammals. Its lower border

is transverse, while its upper border sweeps downwards as it curves out. A shallow groove marks its surface in the middle line, corresponding with the position of the basilar artery. Its fibres are gathered together on each side to enter the cerebellum, and are termed the *middle peduncles* of the cerebellum where they enter its substance, each in contact with an *inferior peduncle* continuous with the restiform body below, and with a *superior peduncle* above, passing up from the cerebellum to the corpora quadrigemina. In gathering together to form the middle peduncle of the cerebellum, the superficial fibres, starting from the upper half in the middle line, turn down so as to overlay those of the lower half, and are distinguished as the *oblique band*, and directed particularly to the under half of the cerebellum.

Internal structure. *In the lower part of the medulla oblongata* the grey matter continued from the spinal cord is first displaced by the decussation of the anterior pyramids, so as to separate, as seen in transverse section, the inner tips of the anterior cornua from the rest, and finally cause them to disappear. At the same time, each anterior pyramid forms a white mass in front; behind and outside it the white substance of the olivary body surrounds the lower end of its own special nucleus; and behind this there is a *lateral nucleus* continuous with the so-called lateral cornu of the cord or outer angle of the clavate enlargement of the anterior cornu. Immediately behind the lateral nucleus there is found the continuation upwards of the gelatinous cornu of Rolando, expanded and termed *tubercle of Rolando*, and having on its surface white nerve-fibres belonging to the root of the fifth nerve; and behind the tubercle of Rolando there are two lobes of grey matter lying under the fasciculus cuneatus and fasciculus gracilis, and named *nucleus cuneatus* and *nucleus gracilis*. Thus the grey matter continuous with that of the cord is thrown greatly backwards and to the sides. But the distance between the central canal and the anterior median fissure is much increased, and is occupied by a decussation of fibres distinct from that of the anterior pyramids, and continuous with the anterior white commissure of the cord, the *decussation of the fillets* (*superior pyramidal decussation*); and the space between this and the series of grey lobes mentioned is occupied by a *reticular formation*, in which vertical bundles occupy meshes between bundles taking transverse and oblique courses.

In the upper or open part of the medulla oblongata a transverse section shows a *raphe* running back in the mesial plane to the grey matter lining the floor of the fourth ventricle in uninterrupted continuity with the grey matter of the cord; and on each side are three areae, anterior, middle and posterior, separated by nerve-roots coursing between the ventricular floor and the grooves behind and in front of the olivary body. At the pia-matral surfaces of the anterior and posterior areae, the fibres of the anterior pyramid and the restiform body respectively stand out compactly, while in the olivary body is seen the olivary nucleus, about to be described, and throughout the deep part there extends a peculiar netted appearance, the *reticular formation* already alluded to, which is caused

by the decussation of fibres taking a more or less nearly horizontal course, with others more nearly vertical, and is continued up through the posterior part of the pons Varolii. In the lateral area the reticular formation has small nerve-corpuscles scattered through it, and is distinguished as *grey*, while that in the anterior area is called *white*.

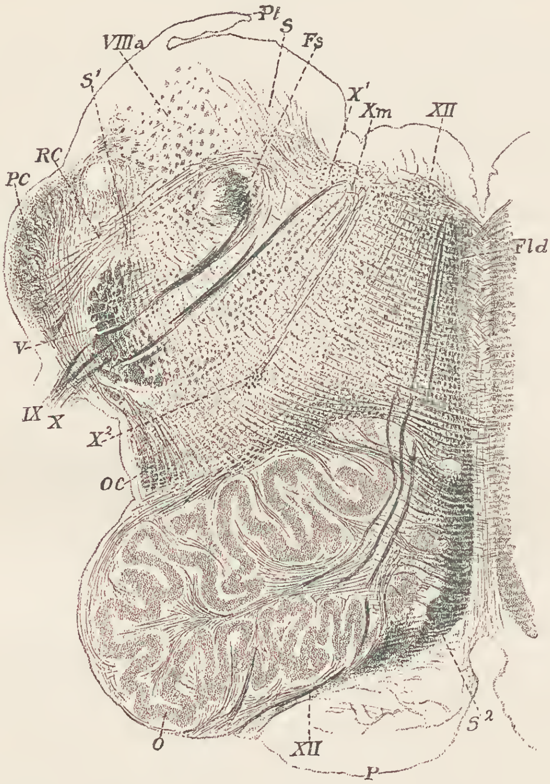


FIG. 432.—MEDULLA OBLONGATA OF FOETUS OF 8 MONTHS. *P*, Pyramid as yet devoid of white substance; *O*, olive with accessory olives; *OC*, olivary cerebellar fibres; *Pt* (ponticulus), ligula; *IX*, *X*, roots of glosso-pharyngeal and vagus; X^1, sensory vago-glosso-pharyngeal root; *Fs*, funiculus solitarius; *Xm*, motor vago-glosso-pharyngeal root bending round; X^2, motor vago-glosso-pharyngeal nucleus (nucleus ambiguus); *V*, sensory root of fifth; *VIIIa*, principal auditory root; *Fld*, posterior longitudinal bundle; *S*, S^1, median and lateral divisions of fillet; S^2, interolivary part of fillet; *PC*, *RC*, inferior peduncle of cerebellum. (v. Kölliker.)

The *olivary nucleus* (*inferior olive* or *corpus dentatum*) is a thin corrugated capsule or pouch of grey matter occupying the length and breadth of the olivary body, with white matter round about it and in its interior, and with a *hilum* or opening of the pouch directed inwards. It is characterized throughout by numerous multipolar corpuscles of small size. An outer and an inner accessory olivary nucleus are described behind and in front of it, and may be seen in transverse section. A *superior olive*, not much developed in man, consists of similar corpuscles above the principal nucleus, placed in the pons Varolii, behind the transverse fibres.

Transverse portions of fibres. The transverse fibres of the pons Varolii are seen in transverse sections to be platted somewhat in the mesial plane, so as to take a deeper course on one side than the other. The same arrangement is manifest to a much greater extent in ordinary dissection at the upper and lower borders. The strands also decussate in an upward and downward direction, the oblique band already noticed having others parallel to it placed more deeply. Thus it is certain that the fibres do not unite corresponding portions of the cerebellum. Some of the deepest fibres lie on one side behind the fibres from the anterior pyramids, and on the other in front of them; and their decussation gives in transverse section the appearance of a projecting point, while, in the same way, others pass on one side behind, and, on the other, in front of a deeper longitudinal band, *the fillet*, causing by their decussation a projection backwards. Transverse fibres are abundant

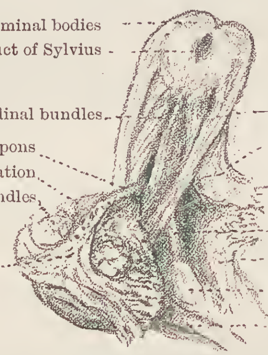


FIG. 433.—PONS DETACHED FROM CEREBELLUM AND REFLECTED FROM THE FILLETS AND POSTERIOR LONGITUDINAL BUNDLES.

in the medulla oblongata also. They form, along with neuroglia, the *raphe*, as they course backwards or forwards in the mesial plane; and they are distinguished as the *superficial* and *deep arched fibres.* The superficial set escape from the raphe in front, and cross the anterior pyramid and the olivary body, or the olivary body only, as they pass back to join the restiform body. Of the deep arched fibres a number pass through the hilum into the capsule of the olivary nucleus, and some of these, together with others, run, like the superficial set, to the restiform body, and so to the cerebellum, while their inferior connections are undetermined. A large number more of the deep fibres pass backwards and downwards to the nucleus cuneatus and nucleus gracilis, while, traced in the other direction, they are found to be continued upwards on the opposite side in the band called the *fillet*, going to the corpora quadrigemina, and form, as they cross the mesial plane, the already mentioned *decussation of the fillets.*

Longitudinal fibres. The anterior pyramids have their fibres continued up into the pons Varolii, first as a pair of round bundles and afterwards

in more flattened form, to be still more flattened in the crusta or inferior part of the crura cerebri. Followed downwards, the internal half of their fibres divide into several strands, which decussate with their fellows of the opposite side; while, at the same time, they become deep, and are continued into the lateral columns of the spinal cord. The outer fibres are thus approached to the anterior longitudinal fissure, and extend down on its sides as the direct pyramidal tracts (*columns of Türck*). A distinct strand from the anterior column of the cord, outside these latter, passing obliquely backwards and upwards over the lower part of the olivary body to join the restiform body, constitutes the *arciform fibres* of Solly. The remaining fibres of the anterior column of the cord and the anterior half of the superficial fibres of the lateral column pass up into the olivary body, the reticular formation and a band called the posterior longitudinal bundle; while the remainder of the lateral column of the cord—namely, the direct cerebellar tract—joins with the cuneate fasciculus or tract of Burdach to form the restiform body. The tract of Goll is continued into the funiculus gracilis or clava. The fibres, however, of the clava do not enter the cerebellum, but would appear to end in the nucleus gracilis; and probably those of the cuneate fasciculus end mostly in the nucleus cuneatus. Among the longitudinal fibres passing up through the deep part of the pons may be mentioned the posterior longitudinal bundles and the fillets. The *posterior longitudinal bundle* lies side by side with its fellow, only some fibres from the raphe intervening beneath the floor of the fourth ventricle. The *fillet* (*lemniscus*), already alluded to, passes upwards and outwards, and divides into two parts, *mesial* and *lateral*, one for the corpora quadrigemina, and the other to join the crusta.

The floor of the fourth ventricle and the roots of nerves connected with it. The floor of the fourth ventricle is a lozenge-shaped surface of grey matter flooring a space communicating with the third, and through it with the lateral ventricles, and lined, as are also these others, with ciliated epithelium, which is not, however, columnar like that of the central canal of the cord, but more or less flattened. The inferior angle is at the termination of the central canal, between the clavae; the superior angle, situate behind the corpora quadrigemina, opens into the aqueduct of Sylvius; and the lateral angles are formed by a *lateral recess* at each side, continued into the peduncle of the flocculus, in the angle between the restiform body and the cerebellum, so that the lower half of the lozenge belongs to the medulla oblongata and the upper half to the pons. From the lateral recess there extend directly inwards two small bundles of white lines—*striae acusticae*; and below this level, on each side, there is a depression, *inferior fovea*, bifurcating downwards; while above it there is a *superior fovea*. The part internal to the inferior fovea contains the upper part of the nucleus of cells from which springs the hypoglossal nerve, and whence its fibres strike forwards between

the posterior longitudinal bundles. The hypoglossal nucleus runs into the anterior cornu of the cord; and close to it externally, but scarcely reaching to the fourth ventricle, is the upper end of the nucleus of the spinal accessory nerve, the lower fibres of which come also from the cord, from the outer part of the anterior cornu. Opposite the inferior fovea the glosso-pharyngeal nerve takes origin, while the vagus takes origin continuously with it, from the elevation (*ala cinerea*) inclosed by the bifurcation of the inferior fovea; but a rounded bundle placed more deeply (*funiculus solitarius*) adds fibres from a lower level to both these nerves. The auditory nerve can be easily seen at its superficial origin to come partly round by the outside of the restiform body and partly through the texture internal to it. It arises from the transverse district between the fovea superior and fovea inferior. Its principal cells of origin, constituting the *dorsal* nucleus, are dorsal and internal to the restiform body; but there is a *nucleus of the external root*, which is closely connected with the peduncle of the flocculus, and also an *accessory nucleus* between the two roots. A number of the fibres cross the middle line. The nucleus of the facial nerve is external to the fovea superior, and that of the sixth nerve internal to it. Further up, near the upper margin of the pons, and to the side of the upper end of the fourth ventricle, lie the *motor* nucleus of the fifth nerve and a large collection of nerve-cells external to it, the *sensory nucleus*, both of them on a level with the emergence of the nerve, the fibres of the sensory part passing through the pons in a direct line, and those of the motor part arching with an upward convexity. Beyond these nuclei additional roots can be followed both upwards and downwards. The inferior or retroserial root has been alluded to as clothing the tip of the prolongation of the gelatinous substance of Rolando; the superior or proserial root is traced to underneath the corpora quadrigemina, and at all levels a certain number of fibres cross the

FIG. 434.—MEDULLA OBLONGATA, CORPORA QUADRIGEMINA AND FLOOR OF FOURTH VENTRICLE, with diagram of nuclei of origin of nerves (5 to 12); those near the surface white, those more deeply placed dotted. *cl*, Clava; *f*, mesial furrow; *e*, eminentia teres; *a*, ala cinerea; *fa*, fovea anterior; *str*, inferior cerebellar crus; *br*, middle crus; *b*, superior crus. (Toldt.)

mesial plane. Internal to the superior root of the fifth nerve, beneath the aqueduct of Sylvius, are placed the nuclei of the third and fourth nerves. A few of the fibres of the third nerve cross the middle line from the nucleus of the opposite side. All the fibres of the fourth nerve, after passing up round the aqueduct of Sylvius, decussate in the middle line of the valve of Vieussens, close to its attachment to the corpora quadrigemina.

III. THE CEREBELLUM AND ANTERIOR VELUM.

The cerebellum is united to the rest of the brain by three pairs of peduncles and the valve of Vieussens, all in immediate contiguity, so as to be cut across in one continuous section. The *superior peduncles* are somewhat flattened bands passing upwards to the posterior quadrigeminal bodies, and are joined together across the middle line by a thin lamina,

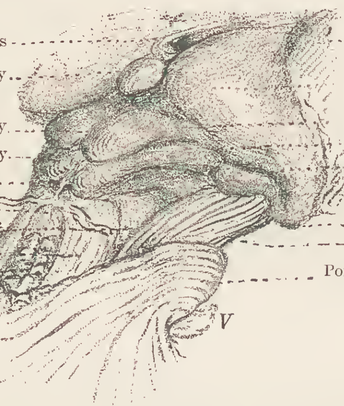


FIG. 435.—VALVE OF VIEUSSENS, or anterior velum, with the corpora quadrigemina, optic thalami and pineal body. The laminae of the cerebellum are removed.

the valve of Vieussens. The *middle peduncles* are continuous with the pons Varolii, and the *inferior peduncles* are apparently continuous with the restiform bodies; but it is to be noted that the restiform bodies include the funiculi cuneati, whose fibres are not directly continued into the cerebellum, while the inferior peduncle includes fibres from the olivary body of the opposite side which are not part of the restiform body.

The **valve of Vieussens** (*anterior medullary velum*) may be at once described, though not counted a part of the cerebellum. It is a thin but strong lamina about an inch in length, easily split in the middle, and consisting mainly of longitudinal fibres. It passes posteriorly into the cerebellum, and anteriorly into the corpora quadrigemina, while it is attached on each side to the inner edge of the superior peduncle of the cerebellum. It is clothed with pia mater on its upper surface; its under surface forms the fore part of the roof of the fourth ventricle. On its fore part, close behind the corpora quadrigemina, the roots of the fourth

pair of nerves, coming up from beneath the floor of the aqueduct of Sylvius, decussate in the middle line, and proceed transversely outwards, adherent to its surface, to reach the crura cerebri, and turn round them. On the posterior half or more of its upper surface, it is overlaid by a series of about six simple grey laminae like those of the cerebellum and serial with them, but growing from the valve and adherent to it, termed the *lingula.*

The **cerebellum** consists mainly of two *lateral lobes* or *hemispheres*, between which there is the *posterior cerebellar* notch behind, and concealed in a *vallecula* below is a distinct mesial part, the *inferior vermiform process*; while superiorly there is a mesial elevation sloping gently backwards and to the sides, in no way marked off from the lateral lobes, which has been called the *superior vermiform process*, and, together with the inferior vermiform process and the intervening district, has come to be termed the *body* of the cerebellum, in consequence of a division into a more distinct body and smaller lateral lobes being common among mammals. Nevertheless one original embryonic pouch is the source of the whole cerebellum, and this pouch does not throw out lateral offshoots but only becomes laterally expanded, the vermiform processes appearing late, and the whole human cerebellum corresponding with the undivided form of the organ found in the non-mammalian vertebrates. The vestige of this primitive pouch furnishes to the cerebellum its small amount of ventricular surface, which, together with the valve of Vieussens, forms the medullary roof of the fourth ventricle, and is placed between the peduncles of opposite sides, between that valve in front and the free margin of a delicate membrane behind, to be presently described, called the posterior medullary velum.

The whole pia-matral surface is composed of grey matter, and is thrown into *folia* or *laminae*, which, when divided vertically, either in the mesial plain or in directions radiating from the peduncles, give the appearance of a branching leafy stem called *arbor vitae*, caused by simple laminae, grey on the surface, being separated by sulci into which the pia-mater dips, these simple laminae being grouped to form larger laminae, and these again being mostly collected into larger lobules with deep sulci or fissures between, the most important of which is the *great horizontal fissure*, continued uninterruptedly round, so as to separate the upper from the under surface, and extending from one middle peduncle to the other.

Lobules. On the upper surface, the foremost lobule forms part of the superior vermiform process and is continuous with the lingula in front, looking forwards and projecting over it. It is called the *central lobe*, and is prolonged into two *alae* on the anterior margins of the hemispheres. Behind it there is a large collection of laminae, consisting of a mesial *monticulus* divided into the *culmen* and the *declivus*, and a great *quadrangular* lobe on each side, correspondingly divided into *anterior* and *posterior lunate lobe.* Behind this there are laterally the *superior semilunar lobes*, which are joined in the middle by a narrower part, the *tuber vermis.* On the under surface in each hemisphere, posteriorly, is placed the *inferior semi-*

lunar lobe, and in front of it the *lobus gracilis*. These both curve forwards externally as far as the anterior margin of the hemispheres; and, circumscribed by them to the outside and behind, the anterior and inner part of the hemisphere is formed by two more compact lobules consisting of shorter laminae taking a direction more backwards and upwards, namely, the *biventral*, or *cuneate lobe*; and, internal to it, looking into the vallecula, the *amygdala*. The inferior vermiform process presents three groups of laminae in front of the tuber vermis. Hindermost the *pyramid* is its broadest part, and, together with the narrower part in front of it, the *uvula*, it dips farthest down into the fourth ventricle, while in front of the uvula the *nodule* or *laminated* tubercle projects forwards, underlying the primitive ventricle, and has its base continued on each side into the

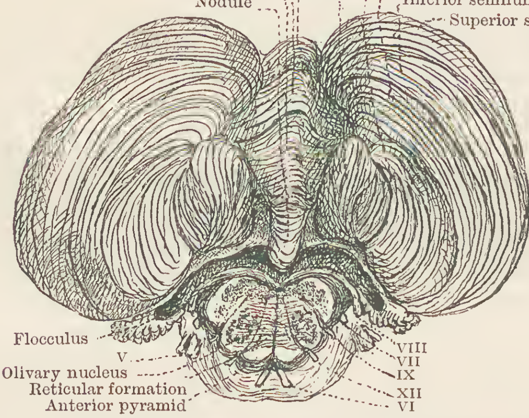


Fig. 436.—Cerebellum from below, with pons Varolii and section through medulla oblongata.

posterior medullary velum already mentioned, a thin translucent membrane of white substance, with a free edge looking forwards. Externally the free edge of the posterior velum is continued on to the stem or peduncle of a minute lobe deserving further attention, the *flocculus*.

The *flocculus* (*subpedunculated lobe*) is in its development no mere lobule of the cerebellum similar to the others, but is a lateral outgrowth of the floor of the cerebro-spinal cylinder, while the rest of the cerebellum is a mesial extension of the roof further forwards.[1] It lies beneath the cerebellar peduncles and in front of the cuneate lobe, the peduncle of the flocculus being close to the origin of the auditory nerve. The peduncle of the flocculus has a groove which extends its whole length, and on into the flocculus itself from the lateral recess of the fourth ventricle, one margin of the groove being continuous with that of the ligula and

[1] In the rabbit and some other animals it is lodged in a deep hollow in the pars petrosa of the temporal bone.

the other with that of the posterior medullary velum. The groove is thus a ventricular epithelial surface, to be distinguished from the pia-matral surface round about, and so turned round by the redundant bulk of the cerebellum that its cerebellar edge lies lower than the ligulae.

Internal structure. *Deeply placed centres of grey matter* are found in the cerebellum independent of the grey matter of the surface, and consist principally of a pair of corrugated purselike sheets, similar in appearance to the olivary bodies of the medulla oblongata. They are called *corpora dentata*, and are situated one on each side, not far from the ventricular aspect. Between them, above the roof of the fourth ventricle, Stilling describes some nodular patches of grey matter in pairs, namely, the *nucleus fastigii*, *nucleus emboliformis*, and *nucleus globosus*. There seems room for some doubt of their independence of the laminae.

Fig. 437.—Frontal Section of Body and Left Lobe of Cerebellum. The left corpus dentatum is seen in the centre of the lobe. A section of the uvula overhangs the medulla oblongata, and between the two the cruciate form of the choroid plexus of the fourth ventricle is displayed.

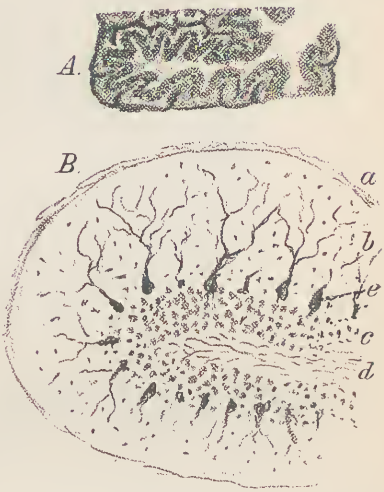


Fig. 438.—Sections of Cerebellum. *A*, Transverse section of lamina or folium, showing the pinnate arrangement of leaflets, $\frac{3}{1}$; *B*, leaflet more highly magnified: *a*, pia mater; *b*, molecular layer with thinly scattered granules; *c*, granular layer; *d*, central white matter; *e*, corpuscles of Purkinje.

The *superficial* or *cortical grey matter* clothing the laminae has a complicated structure peculiar to it. It is divided abruptly into two strata, the superficial of which, somewhat the thicker of the two, is called the *molecular* layer, while the deeper is called the *granular* and is of a slightly redder grey. The granular layer gets its name from presenting, even under a low power, granules scattered thickly through all its substance. These granules have now been demonstrated by Golgi's method to be minute nerve-corpuscles averaging $\frac{1}{5000}$th inch in diameter, each with three or four short branching protoplasmic processes and a very fine axis-cylinder-process which passes up through a variable depth of the molecular substance, there to divide into two branches taking their courses in opposite directions parallel

to the surface and along the length of the lamina, and ending in bulbous extremities. Also the granular layer presents a certain number of *large stellate nerve-corpuscles*, and it has the whole of the nerve-fibres of the underlying white matter coursing on through it to reach the molecular layer. The molecular layer contrasts with the granular in presenting a much smoother appearance under the microscope. On its floor there is a single stratum of large nerve-corpuscles, *corpuscles of Purkinje*, pretty closely set, each having at its base or deep part continuity with a medullated nerve-fibre direct from the white brain-matter of the centre of the lamina, and, at its superficial extremity, a single protoplasmic pole at once breaking up dichotomously into a number of processes which make for the surface. The main branches can be easily seen with the usual modes of staining, but a much more extensive arborization is brought into view by means of the Golgi method; and this arborization is spread out in a plane

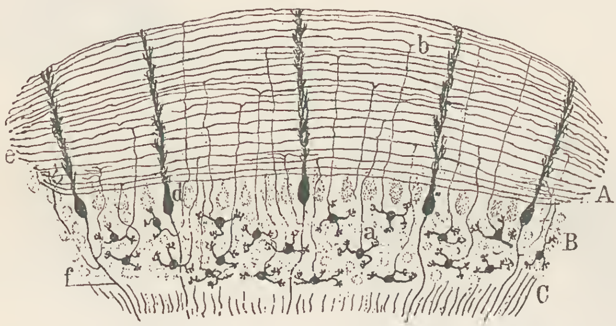


FIG. 439.—SEMI-DIAGRAMMATIC LONGITUDINAL SECTION OF CEREBELLAR LAMINAE. A, B, C, Molecular, granular and white layers: *a*, ascending axis-cylinder of grain-like corpuscle; *b*, bifurcation of the same, and formation of a parallel fibre; *d*, profile view of corpuscles of Purkinje; *e*, thickened free extremities of parallel fibres; *f*, axis-cylinder of corpuscle of Purkenje. (Cajal.)

transversely crossing the lamina, so that in longitudinal sections of laminae the arborizations of the corpuscles of Purkinje are seen as hedgelike septa, while the intervening spaces are, as it were, ruled with the lines of the divisions of the axis-cylinder-processes of the corpuscles of the granular layer. There are likewise in the molecular layer, placed at different levels, *small stellate nerve-corpuscles* transversely flattened, and having the axis-cylinder-process much elongated in the transverse plane and parallel to the surface of the lamina, with terminations and collaterals descending and breaking into copious ramifications, *the terminal baskets of Kölliker*, surrounding each corpuscle of Purkinje and curving inwardly round its axis-cylinder. Cajal recognises three kinds of nerve-fibres in the central white matter, namely, (1) descending fibres coming from the corpuscles of Purkinje and giving off a certain number of ascending or recurrent collaterals; (2) thick nerve-fibres ascending and ramifying in the granular layer in "*mossy*" branches; (3) other thick fibres ascending to ramify in the molecular layer, and these he terms clambering fibres.

Disposition of fibres within the cerebellum. If the horizontal fissure, in a conveniently prepared cerebellum, be torn open, it will be found that the corpus dentatum is embedded in fibres below that fissure, and appears to receive into its interior the fibres of the superior peduncle; the fibres of the middle peduncle are arranged in interdigitating fasciculi, those from the upper half of the pons passing to the lower part of the cerebellum, and those from the lower part of the pons going to the upper part of the cerebellum, some of them crossing the middle line (Fig. 435); and the fibres of the inferior peduncle pass up between the two sets of fibres spread

Fig. 440.—Semi-diagrammatic Transverse Section of Cerebellar Lamina of Mammal. A, Molecular layer; B, granular layer; C, white substance: *a*, corpuscle of Purkinje in front view; *b*, small stellate corpuscles of molecular layer; *d*, terminal descending arborizations surrounding Purkinje's corpuscles; *e*, superficial stellate corpuscles; *f*, large stellate corpuscles of the granular layer; *g*, grain-like corpuscles with ascending axis-cylinders bifurcating at *i*; *h*, mossy fibres; *j*, neurogliar corpuscle with plume; *m*, neurogliar corpuscle of the granular layer; *n*, clambering fibres; *o*, ascending collaterals from the axis-cylinder of Purkinje's corpuscles. (Cajal.)

out below the horizontal fissure, namely, those of the superior peduncle internally and the lower fibres of the middle peduncle externally, and mingle with the ascending fibres of the middle peduncle. The fibres belonging to the inferior vermiform process pass outwards above the fibres of the superior peduncle.

Roof and choroid plexus of fourth ventricle. The ventricular surface of the valve of Vieussens and of the cerebellum, back to the posterior medullary velum, constitutes the roof of the fourth ventricle, so far as that ventricle is roofed by brain-matter coated with epithelium. But the free

edge of the posterior velum is the upper margin of a gap in the roof of the cerebro-spinal cylinder, and the remaining boundary of the gap passes round by the groove of the floccular peduncle and the free edge of the ligula on each side. Over the gap the pia mater is spread, sending in a fringe of choroid plexus which follows the course of its boundaries, completing a ring bent in so as to give it the shape of a cross or of the letter T, the lateral parts extending outwards to the flocculi, the lower parts lying internal to the ligulae, and the upper part being sometimes carried forwards in the middle line on the nodule, but sometimes running straight across. In the undisturbed condition it wreathes round the pendent uvula, which has its own covering of pia mater, like the other folia of the cerebellum. The fourth ventricle cannot be opened by separation of the medulla oblongata from the cerebellum without injury to the pia mater. It is a mesial tear made in this way below the extremity of the choroid plexus, which is described by Luschka under the name of *foramen of Magendie* and is figured by the most recent writers and supposed by them to be natural. It can easily be demonstrated to be artificial, if the dissector be on his guard; but it is not easy to make certain if there is within the circuit of the choroid plexus a layer independent of the proper investment of the uvula and nodule.[1]

IV. THE ROOT PART OF THE CEREBRUM.

The *isthmus cerebri* is a somewhat irregularly shaped cylinder, rendered ventrally bilobate by the outward and upward direction of the two crura cerebri, which, issuing from the pons Varolii, form its greater bulk, while it is completed dorsally by two comparatively small bands, the superior peduncles of the cerebellum, with the valve of Vieussens between them roofing the upper part of the fourth ventricle. Between the crus cerebri and the superior peduncle of the cerebellum, in the fore part of the distance from cerebellum to corpora quadrigemina, there is an elevation on each side caused by the fillet (its lateral division) passing up to the corpora quadrigemina.

The *corpora quadrigemina* is the name given to a body about half an inch long, and three-eighths broad, composed principally of grey matter, but having a white surface, covered with pia mater, looking backwards

[1] The utility of the foramen of Magendie is supposed to be to allow passage of fluid from the brain to the spinal canal; but Reid and Sherrington have shown that the capacity of the spinal canal is diminished by bending, and it is hard to believe that in stooping it is an advantage to the brain to have fluid propelled into its ventricles. Besides, even if an opening exists, it is obvious that it must be effectually occluded by the choroid plexus when the parts are *in situ*. A supposed ventricular opening is figured at the floccular extremity of the choroid plexus of the fourth ventricle and called *foramen of Luschka*. A similar opening has been alleged to exist at the extremity of the descending cornu of the lateral ventricle. Such openings may be produced by very trifling pressure.

and upwards, and divided by a crucial depression, into a superior larger pair of elevations (*nates*) and a posterior inferior smaller pair (*testes*) with a slight mesial bridle, *fraenulum veli*, behind it. Beneath them is a narrow canal, the *aqueduct of Sylvius* (*iter a tertio ad quartum ventriculum*), continuous with the fourth ventricle and opening in front into the third ventricle between the optic thalami, with grey matter surrounding it continuous with that of the floor of the fourth ventricle, and containing, as already noted, the nuclei of origin of the third and fourth nerves.

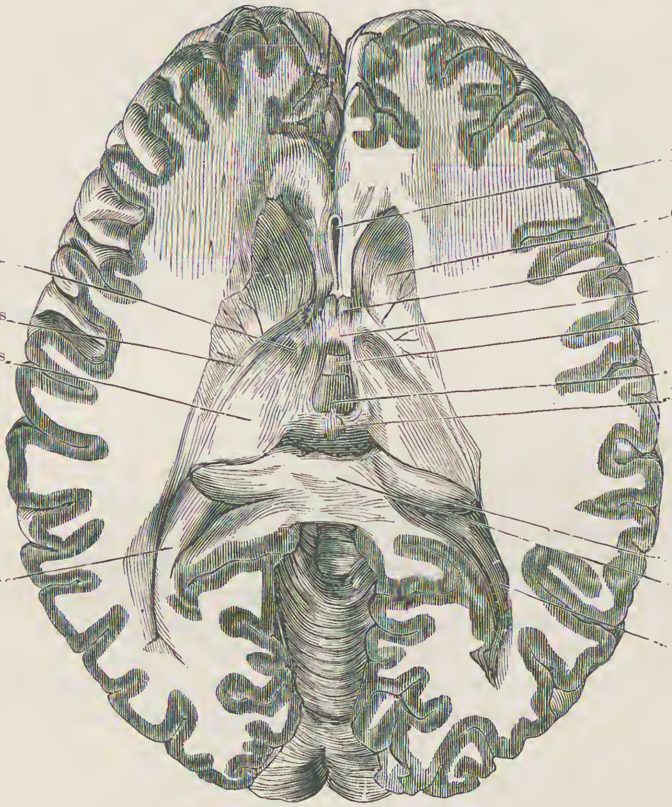


Fig. 441.—Third Ventricle opened by division of fornix and removal of velum interpositum. (Bouchard.)

The *optic thalami* are two large oval bodies looking upwards in front of the corpora quadrigemina, having the free surface white, and in great part, like the corpora quadrigemina, clothed with pia mater; but they have not, like them, continuity of the pia-matral surface across the middle line. Beneath them are the crura cerebri, while from the front and outer sides emerge the fibres continuous with the crura, spreading toward the whole surface of the hemispheres and known as *corona radiata*. The posterior extremity of the optic thalamus projects free, external to the front of the corpora

quadrigemina, and is called the *posterior tubercle*, while the anterior part presents an elevation, the *anterior tubercle*, distinguished by a slight depression running internal to and behind it, so as to indicate the free margin of a superimposed brain-structure, the fornix, which is separated from it by a fold of pia mater, velum interpositum, whose redundant vascular margin, the choroid plexus of the lateral ventricles, more or less overlies the anterior tubercle. The upper surface of each optic thalamus is separated by a furrow in front and on the outer side from the corpus striatum.

The *corpora striata* present each a large pyriform elevation of grey matter, the *caudate nucleus*, in front and outside of the optic thalamus; its fore part being broad and rounded, and separated from its fellow by the anterior pillars of the fornix and by the septum lucidum, while posteriorly it tapers to a point outside the hinder end of the optic thalamus. There are two other nuclei of the corpus striatum placed deeply, namely, the *lenticular nucleus* and the *claustrum*, and all three lie back to back with the island of Reil, forming with it the root part of the hemisphere, while the rest of the hemisphere, distinguished as the *mantle* (Reichert), has no grey matter except on the convoluted surface.

The *taenia semicircularis* or *stria terminalis* is a narrow band in the furrrow between the optic thalamus and corpus striatum. It is a gelatinous-looking structure, containing a vein and some white nerve-fibres, but is principally interesting as an embryological landmark.

The floor of the third ventricle. The mesial surfaces of the optic thalami are nearly in contact one with the other, forming the lateral walls of the third ventricle, and covered like other ventricular surfaces with ependyma and ciliated epithelium. They are very usually united across the middle line by a little bridge of grey matter, the *middle, soft* or *grey commissure of the third ventricle*, but this is often absent. The floor of the ventricle slopes downwards and forwards, supported at first by the tegmentum of the crura cerebri; and in front of this it is simply the thin grey lamina constituting the tuber cinereum, and exhibits the mouth of the infundibulum leading to the pituitary body, while, still further forwards, it forms a pointed cul-de-sac, the *optic recess*, on the upper surface of the optic commissure, and bounded anteriorly by the lamina cinerea. At the back of the third ventricle the opening of the aqueduct of Sylvius is seen, and over it a transverse band, the posterior white commissure of the third ventricle with the pineal body attached to it. At the front of the ventricle, just above the optic recess, two cylindrical white cords, the anterior crura of the fornix, descend to disappear in the grey matter on each side; and immediately in front of them there is a transverse white cord, the anterior commissure of the third ventricle (Figs. 446 and 449).

The pineal body or conarium is a small structure like a currant, of a slightly flattened and conical shape and deep reddish colour, attached by a narrow neck to the posterior white commissure, and surrounded with pia mater, or, rather, embedded in it, resting on the front of the corpora quadrigemina. In

its structure it presents a number of crypts containing epithelium, and supported by connective tissue. The crypts are the seat of numerous nodulated concretions of lime salts, which can be felt like sand when the substance is laid hold of with the forceps, and are known as *acervulus cerebri.* The pineal body is better developed in young subjects and in at least some mammals than in the human adult.[1]

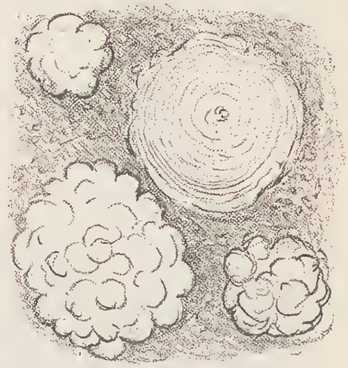


FIG. 442.—CONCRETIONS of acervulus cerebri in tissue of pineal body. Three show their nodulated surfaces, while the fourth is focussed for its centre, to display the lamination round a shrivelled corpuscle.

The *posterior white commissure* of the third ventricle is not a cylindrical band as at first sight it appears, but a thin sheet of white substance prolonged forwards from the corpora quadrigemina, and folded back on itself. Its free edge is again turned slightly forwards, and where so turned has the pineal body attached to it mesially, while on each side it is prolonged forwards on the optic thalamus at the margin where the white upper surface of that body meets the grey surface opposed to its neighbour. The prolongations are called *pineal crura* or *striae*, and the recess between these, the *pineal recess.* The whole arrangement gives the appearance as if the posterior commissure had formed a primordial roof to the third ventricle, with the pineal body at its fore end, and as if the vascular connections of the latter or some other cause had held it back while the optic thalami grew in a forward direction.

The *anterior white commissure* is a small round fasciculus of white nerve-fibres visible in the anterior wall of the third ventricle, close in front of the anterior pillars of the fornix, as these descend and turn backwards to the corpora albicantia. Its fibres pass into the part of the corpora striata known as the internal capsule. It is distinct even in birds, though they have no other commissure of the hemisphere-vesicles.

The *pituitary body* is a tough reddish structure, occupying the sella turcica, in a special recess of the dura mater, the opening of which is contracted and surrounded by the circular venous sinus. It consists of an anterior and a posterior lobe. The anterior lobe, much the larger and somewhat embracing the posterior, is a prolongation upwards of the roof of the stomodaeal epiblast, and exhibits throughout life columns of closely-set cor-

[1] Descartes imagined the pineal body to be the seat of the soul. Geoffroy St. Hilaire looked on it as a vestigial structure indicating a primeval entrance to the alimentary canal between the lateral halves of the central nervous system, such as occurs among invertebrata; and his view was afterwards favoured by Goodsir, and still later by Owen (1881). In recent years it has been noted that in elasmobranch fishes and various reptilian forms the pineal body actually is connected tubularly with a vesicle beneath the skin, which is spoken of as a vestige of a mesial parietal eye.

puscles with trabeculae between, like the columnar part of the cortex of the suprarenal body; the posterior part, truly cerebral in origin, is a prolongation downwards from the infundibulum, but like the pineal body fails to exhibit in mammals any nervous structure, and is composed of a variety of connective tissue, which may be looked on as thickened neuroglia.[1] (See also pp. 97 and 245.)

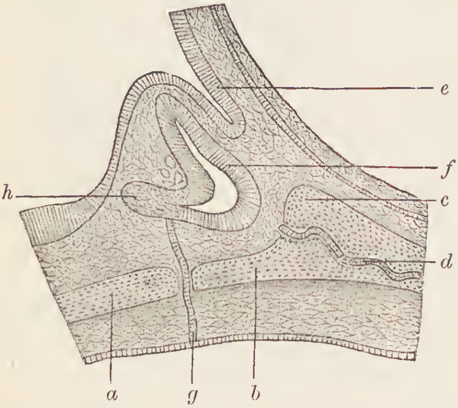


FIG. 443.—MESIAL SECTION OF PITUITARY BODY AND SURROUNDINGS. Rabbit $\frac{4}{5}$ inch long. *a*, *b*, Presphenoidal and postsphenoidal cartilage; *c*, dorsum sellae; *d*, notochord; *e*, infundibulum; *f*, hypophyseal pouch; *g*, duct of the same; *h*, process filled with rounded cells, while the pouch is lined with columnar cells. (Mihalkovics.)

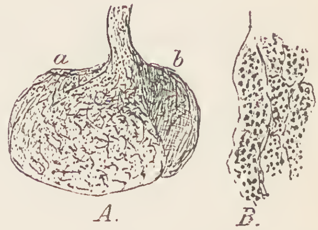


FIG. 444.—PITUITARY BODY. *A*, mesial section: *a*, anterior or glandular part projecting up into infundibulum; *b*, posterior or cerebral part, $\frac{4}{1}$. *B*, Portion of anterior part more highly magnified.

The optic tracts and commissure. A retreating angle is left between the posterior tubercle of the optic thalamus and the side of the corpora quadrigemina, and in this angle are seen two small elevations, the *outer* and the *inner geniculate body*, connected with the optic tract. The optic tracts traced backwards divide into a larger outer and a smaller inner root, the outer entering the outer geniculate body, which is also the larger, and the inner passing to the inner geniculate body. The outer root continues from the outer geniculate body to the superior corpus quadrigeminum, partly directly along a ridge called *anterior brachium*, partly by turning over the posterior tubercle of the optic thalamus; a strand also of its fibres passes by the posterior tubercle to the corona radiata, and forms a *direct cortical tract* (Gudden). The inner root is continued by the *posterior brachium* to the inferior corpus quadrigeminum.

The optic tracts, united to the crura close to the line along which they

[1] The pituitary body presents a puzzle not only in development but in function; and it can only be pointed out as remarkable that great enlargement of this body has been observed as a very frequent accompaniment of a curious hypertrophic disease affecting many parts of the body and named Acromegaly by its discoverer, Dr. Pierre Marie. Perhaps the mental symptoms in cases of Acromegaly make it not improper in this place also to note that "naso-pharyngeal adenoids," hypertrophic growths of the region from which the larger part of the pituitary body took origin, are notably liable to affect the mental powers.

become covered by the hemispheres, extend onwards to the *optic commissure* or *chiasma*, where the fibres of each divide into two parts, one travelling to the retina of the same side, and the other decussating with its fellow of the opposite side and going to the other eye. Fibres also pass from one tract to the other in the inferior and hinder part of the chiasma (*commissure of Gudden*), and are said to join together the two internal geniculate bodies. It is to be noted that the arrangement of a chiasma with partial decussation occurs only in mammals. In fishes and reptiles the one optic stem may cross the middle line free from the other, without division into tract and nerve at that point.

Deep structure of root of cerebrum. The crura cerebri are divided into two parts—the *crusta* or ventral part, and the *tegmentum* or dorsal. It is only the crusta which is completely divided into two pillars. A transverse vertical section through the corpora quadrigemina and crura shows grey matter of the corpora quadrigemina separated by a white streak from that which surrounds the aqueduct of Sylvius in continuity with the floor of the third and fourth ventricles, and beneath and around this the tegmentum, separated by a definite outline from the crusta below. The crusta consists of the continuation upwards of the anterior pyramid of the medulla oblongata, greatly added to by other fibres from sources not easy to determine, though some of their fasciculi are distinctly traceable by dissection from the middle peduncle of the cerebellum. It passes on beneath the optic thalamus into a broad white tract, called the *internal capsule*, beneath the nucleus caudatus of the corpus striatum, and spreading out toward every part of the cortex of the hemisphere, under the name of corona radiata. In the plane of contact of crusta and tegmentum there is a broad sheet of blackish hue extending outwards from the middle line where overlapped by the pons Varolii; it is called the *substantia nigra*, and owes its darkness to pigmented nerve-cells. It may be said to occupy an angular recess continuous with the tuber cinereum and crushed together dorso-ventrally by the unusual thickness of the crusta and the pons Varolii in the human subject. Another very distinct, but much smaller, patch of pigmented cells is likewise placed in a retreating angle, being situated between the superior peduncles of the cerebellum and the posterior longitudinal bundles, where the aqueduct of Sylvius meets the fourth ventricle. It is called *locus caeruleus*, and is in transverse diameter no larger than a pellet of small shot.

The *posterior longitudinal bundle*, already traced up from the neighbourhood of the outer part of the anterior column of the spinal cord, after passing up under the grey matter of the floor of the fourth ventricle, becomes closely connected beneath the aqueduct of Sylvius with the nuclei of the motor nerves to the orbit (3rd, 4th, and 6th), and is prolonged beneath the grey matter of the optic thalamus (as *stratum dorsale* of Forel). The formatio reticularis, much diminished in extent

as it ascends in the tegmentum, has a number of nerve-corpuscles scattered through it; it presents a reddish-grey appearance termed the *red nucleus*, and, more in front, under the optic thalamus, in contact with the crusta, a group of nerve-corpuscles, described as *corpus subthalamicum* by Luys. The fillets, travelling up with an outward inclination, divide each into a lateral and a mesial part. The *lateral fillet* appears for a short distance on the surface, and then crosses over the superior peduncle of the cerebellum to enter the inferior corpora quadrigemina. The *mesial fillet* spreads out and sweeps round to join the crusta. The superior peduncles of the cerebellum, on reaching the corpora quadrigemina, turn down by the outside of the posterior longitudinal bundles, cross the mesial plane, decussating one with the other, and reach the red nucleus, whence they pass on to the optic thalami along with other fibres.

FIG. 445.—SECTION THROUGH CORPORA QUADRIGEMINA AND CRURA CEREBRI. (Bouchard, after Stilling.)

The optic thalamus consists of a continuous mass of grey matter with only a thin layer of white matter, *stratum zonale*, on its surface, and thin and partial septa dividing it into mesial, lateral and anterior nuclei, besides a small collection of large corpuscles beneath the pineal crus, *ganglion habenulae*, whence a band (*fasciculus retroflexus* of Meinert) descends through the tegmentum to the region of the posterior perforated spot. The optic thalamus has the back part of the caudate nucleus of the corpus striatum external to it above, and the internal capsule beneath and external to it, and sends out fibres to radiate with those of the internal capsule to different parts of the cortex of the hemisphere (*crura* and *ansae* of authors).

The corpora striata have three very distinguishable nuclei—*nucleus caudatus*, *nucleus lenticularis* and *claustrum*. The nucleus caudatus is the part which looks into the lateral ventricle, and is separated from the nucleus lenticularis by white matter called *internal capsule*. The internal capsule is seen in horizontal section to change its direction opposite the

front of the optic thalamus so as to form an angle (*genu*), with the posterior limb directed forwards and inwards, and the anterior forwards and outwards. The nucleus lenticularis fills up the retreating angle opposite the genu of the internal capsule, and is connected in its whole length with the nucleus caudatus by streaks of grey matter, from which the corpus striatum takes its name; but it is connected with it most closely in front, where indeed the two nuclei become continuous. The nucleus lenticularis in frontal section is wedge-shaped, divided by two white lines into an outer, a middle and an inner stratum—the first (*putamen*) of a redder colour than the other two (*globus pallidus*). Outside the nucleus lenticularis there ascends a layer of white matter narrower than the internal capsule; it is called the *external capsule*, and contains fibres from the optic

FIG. 446.—VERTICAL TRANSVERSE SECTION in front of the lamina cinerea.

thalamus and the anterior white commissure. It is rounded externally by the claustrum. The claustrum is a very thin sheet of grey matter intermediate in position between the nucleus lenticularis and the convolutions of the island of Reil, and broadening out in its lower and fore part so as to present a triangular form in frontal section. It has spindle-shaped corpuscles with yellow pigment, as has also the globus pallidus. Both nucleus lenticularis and claustrum are connected below with the superficial grey matter at the anterior perforated spot.

V. WALLS AND SEPTA OF THE CEREBRAL VENTRICLES.

The **corpus callosum**, or *great commissure of the brain*, is an arched structure consisting mainly of transversely-arranged white fibres, which join the two hemispheres together in the space left by the circuit of the falx cerebri for more than half their total length. It forms in this extent the floor of the great longitudinal fissure; it ends posteriorly in a thick-

ened extremity, while anteriorly it presents a stout *genu*, prolonged backwards into a completely retroverted part, the *rostrum;* and the rostrum rapidly thins, and ends in a pair of *crura* descending on each side of the lamina cinerea to the anterior perforated spot. The superficial aspect is in contact in its whole extent with a convolution (gyrus fornicatus) of each hemisphere, and is from two-thirds to three-fourths of an inch broad. It has a transverse striation indicating the direction of its bundles, and has a few longitudinal marks, viz., in the

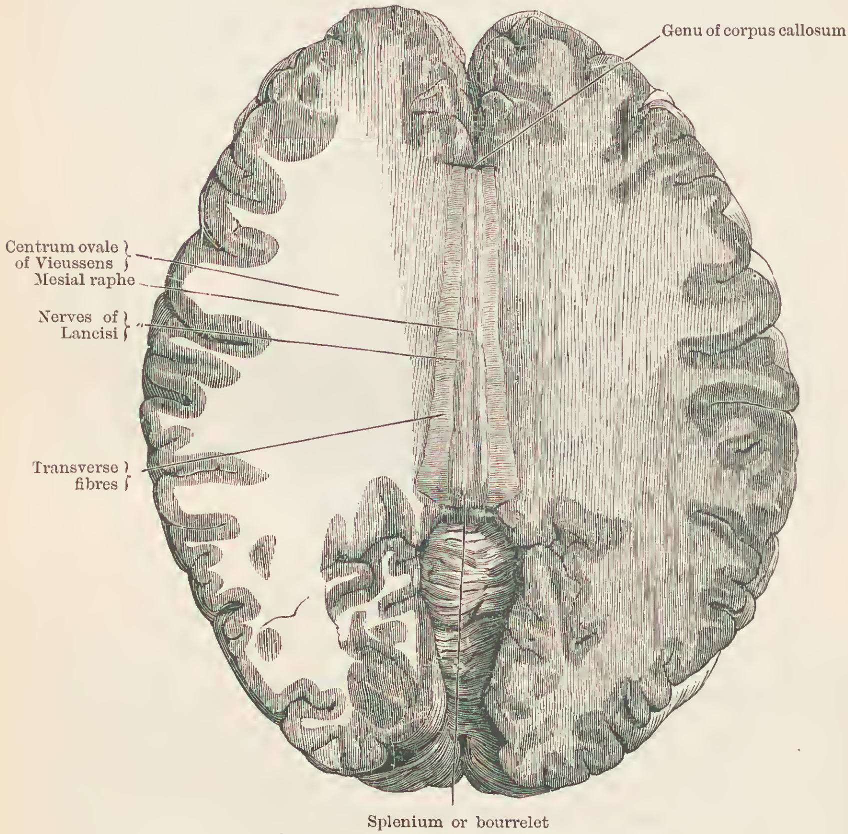


Fig. 447.—Corpus Callosum from above. (Bouchard.)

middle, a longitudinal furrow, divided by a mesial elevation, the *raphe,* best seen in front; to the sides of this, a pair of slightly wavy distinct white threads, *nerves of Lancisi;* and considerably further out, where the overhanging convolutions cease to be in quite close contact, a pair of *grey lateral bands* or striae. A grey coat or *indusium,* containing scattered multipolar corpuscles, a vestigial continuation of the cortex of the cerebral convolutions, though not very evident, covers the whole surface. The deep surface completes the roof and anterior limit of the lateral

ventricles; in the concavity of the genu it is concealed laterally by the corpora striata, and between them gives attachment to the two laminae of the septum lucidum, with the fifth ventricle between; while further back it is directly united to the two lateral halves of the fornix, whose lines of continuity with it recede from the mesial plane as they pass backwards. At its posterior extremity the corpus callosum is about twice as thick as it is further forwards; it may be about a third of an inch in depth, and looked at from below presents behind the fornix a limited projection, broader in the middle, the *splenium*. In front of this a triangular portion, transversely striated, the *lyra*, is seen. At the genu the corpus callosum is again greatly thickened before thinning away in the rostrum. The fibres traced into the hemispheres spread out in every direction, and those in front and behind curve forwards and backwards respectively, constituting the so-called *forceps minor* and *major*. The corpus callosum is occasionally altogether absent. The recorded cases of total absence have usually been accompanied with other deficiency of cerebral development, sufficient of itself to account for the idiocy which in most cases, but not all, has been observed during life.

The **septum lucidum** is the name given to a pair of vertically-placed laminae considered as one structure, but really quite distinct, with their inner surfaces separated by a small mesial space, the fifth ventricle, and their outer surfaces looking into the lateral ventricles. It bridges the distance between the fore half of the corpus callosum and the fornix, being attached to the fornix by an edge looking downwards and backwards, and to the corpus callosum in the rest of its extent, and being of a shape rounded and deep in front but tapering to a point behind. Each lamina is a portion of the wall of the corresponding hemisphere, which has become separated, by the development of the corpus callosum, from the part whose surface looks into the great longitudinal fissure; and although it is flat and only about $\frac{1}{25}$th inch in thickness, it consists of white matter coated with grey on the surface looking towards its fellow and originally continuous with the cortex of the convolutions.

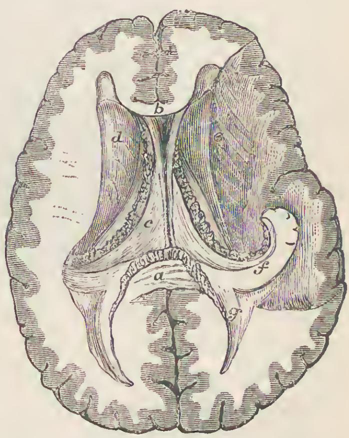


FIG. 448.—THE LATERAL AND FIFTH VENTRICLES. *a*, Posterior fibres of corpus callosum; *b*, genu of corpus callosum, with fifth ventricle below; *c*, fornix and, external to it, choroid plexus; *d*, corpus striatum and, between it and the choroid plexus, part of optic thalamus with stria terminalis in the furrow; *e*, section of corpus striatum; *f*, descending cornu of lateral ventricle with hippocampus major occupying its floor, and fimbria between it and the choroid plexus; *g*, hippocampus minor in the posterior cornu.

The **fifth ventricle**, the mesial space between the two laminae of the septum lucidum, is as much as a tenth of an inch in breadth in front, while its lateral walls come in contact behind. Though originating as a

recess from a pia-matral surface, it has not been followed by the pia mater, and its walls present only a delicate network of vessels embedded in brain-substance, presenting on the surface a scattered layer of corpuscles which may be looked on as epithelioid.

The **fornix**, when looked at from above, with its adhesion to the corpus callosum unbroken, presents the appearance of an arched triangular lamina of white substance, the *body* resting on a deep projection of pia mater of corresponding extent, the velum interpositum. The margins of this triangular body are concave, the lateral being free, with the hypervascular fringe of the velum interpositum, the choroid plexus of the lateral ventricles, projecting beyond them, and the posterior being attached to the corpus callosum, as is also the mesial part of the dorsum, while the anterior angle is prolonged into two round *pillars* or *anterior crura*, and the two posterior angles form a pair of *posterior crura* prolonged each into a flat ribbon, the *fimbria* or *taenia hippocampi.*

The posterior crura of the fornix lie in front of the splenium of the corpus callosum, one on each side, separated by the velum interpositum from the upper surface of the posterior tubercle of the optic thalamus.

The taenia hippocampi, extending outwards beyond the optic thalamus and corpus callosum, turns forwards round the crus cerebri to lie in the floor of what is called the descending cornu of the lateral ventricle, with the choroid plexus entering from the exterior between it and the crus cerebri, while its attached border is continuous superiorly with a convexity of the floor of the descending cornu named hippocampus major, and inferiorly with the grey convoluted surface of the hemisphere. Its fibres in a fresh brain can often be seen spreading obliquely on the hippocampus major, and apparently they make for the cortex of the temporal lobe.

The pillars or anterior crura of the fornix descend side by side between the corpora striata in front of the taenia semicircularis and behind the anterior white commissure, separating as they descend, so that the commissure is seen between them from behind; then turning backwards each becomes covered with the grey lining of the third ventricle on its own side and dips to the corresponding *corpus albicans*, whose main bulk it seems, as seen in dissection, to form by twisting abruptly inwards, forwards and upwards, before it is continued upwards and backwards as the *bundle of Vicq-d'Azyr* to the optic thalamus, in the deep part of which it spreads outwards horizontally. Thus, the fornix unites the optic thalamus and temporal lobe of the same side.

But the **corpora albicantia** (*mammillaria*) are not mere twistings of the pillars of the fornix; they contain grey matter, and experiment would appear to show that the bundle of Vicq-d'Azyr is not directly continuous with the fibres of the pillars of the fornix. Also, there is a bundle passing backwards from each of the corpora albicantia to the inner part of the crusta; and these bodies not only represent a more developed mesial body in lower vertebrates, but are comparatively large in the foetus.

The **velum interpositum** (Fig. 356) is the fold of pia mater corresponding in form and extent with the fornix, beneath which it rests on the optic thalami, continuous behind with the pia mater of the corpora quadrigemina below and with that of the splenium above. Beyond the margin of the fornix it swells out into a stronger and thicker fringe rich in redundant loops of bloodvessels, the *choroid plexus of the lateral ventricle*; and at the side, where the posterior crus of the fornix runs into the taenia hippocampi or fimbria, the pia mater still enters the descending cornu of the lateral ventricle, and the choroid plexus is continued without intervention of a velum interpositum. The continuous fissure by which the velum interpositum enters mesially beneath the fornix, and the pia mater enters the descending cornua of the lateral ventricles, is horseshoe-shaped and is

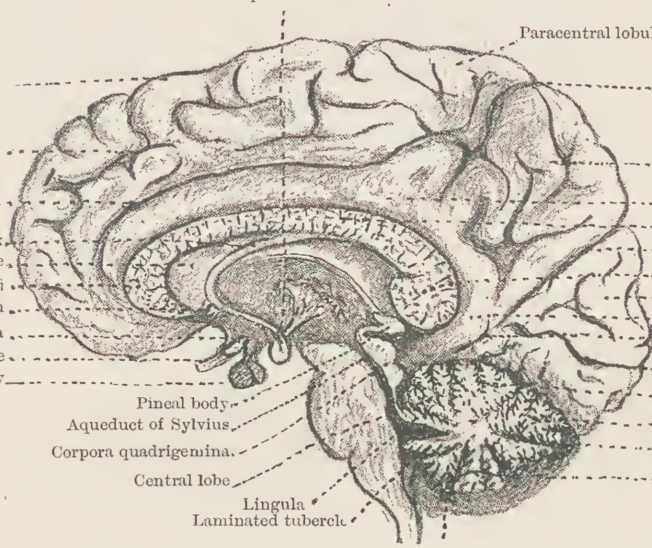


Fig. 449.—Mesial Section of Brain, with the anterior crura of the fornix and the bundle of Vicq-d'Azyr dissected.

called the *transverse fissure of the brain.* The velum interpositum supplies minute vessels upwards to the fornix, and the under surface near the sides sends down branches to the optic thalami. Its principal artery is the anterior choroidal from the internal carotid, which enters at the extremity of the transverse fissure and runs in the whole length of the choroid plexus, receiving anastomotic branches from posterior choroidal branches of the posterior cerebral artery. The blood is returned by a pair of veins running forwards in the choroid plexus, which are joined below the anterior pillars of the fornix by a vein from the surface of the corpus striatum and another from the septum lucidum to form the two veins of Galen; and these pass backwards in the middle to join before opening into the straight sinus.

A pair of small vascular fringes, the *choroid plexuses of the third ventricle,* dip down from the velum interpositum near the middle line, and the ciliated epithelial lining of the third ventricle is reflected over them and extends downwards on the inner surfaces of the optic thalami. The ciliated epithelium is in like manner continued from the upper or ventricular surface of the fornix and taenia hippocampi over the choroid plexuses of the lateral ventricles on to the exposed parts of the upper surface of the optic thalami and the walls of the descending cornua of the lateral ventricles. There is, however, left at one place a communication between the third and the two lateral ventricles, the *foramen of Monro.* This aperture is formed by the anterior angle of the body of the fornix, with the front of the velum interpositum adherent to it, arching over and between the anterior extremities of the furrows of the right and left taenia semicircularis before it dips down in the form of two pillars. Thus, the foramen of Monro is a Y-shaped communication, single below and double above, between the third ventricle and the two lateral ventricles.

The third ventricle is limited behind by the pineal recess, the posterior white commissure and the anterior opening of the aqueduct of Sylvius. Its lateral walls are formed by the opposed grey surfaces of the optic thalami, which are most frequently united to a certain extent in the form of a grey commissure. The floor deepens from behind forwards and presents pretty well forwards an opening leading into the infundibulum, and, quite in front, the optic recess. The anterior wall prevents the pillars of the fornix descending with the anterior white commissure between and in front of them. The roof is formed by velum interpositum and choroid plexuses of the third ventricle, and its communication with the lateral ventricles by means of the foramen of Monro, is in front.

The **lateral ventricles** are the adult condition of the original hollows of the hemisphere-vesicles. They differ from the other ventricles in being surrounded by white substance save where the caudate nuclei of the corpora striata are exposed. From before backwards and inwards there are seen, in the floor of each, corpus striatum, stria terminalis, anterior tubercle of optic thalamus, choroid plexus, and half of the body of the fornix. Each has three cornua. The *anterior cornu* is a short and rounded cul-de-sac projecting into the anterior lobe of the hemisphere, in front of the corpus striatum. The *posterior cornu* is a longer cul-de-sac stretching backwards in the posterior lobe, curved and pointed, the convexity outwards and the point inclined inwards. It presents a convexity of its floor to the inner side, which is named *hippocampus minor*, and is the obverse convexity corresponding to a sulcus (named *calcarine*) on the mesial surface of the hemisphere. The remaining cornu, the *lateral* or *descending*, is longest of all, and is not a cul-de-sac like the others, inasmuch as its nervous walls present in the whole length a breach of continuity, the lateral part of the transverse fissure. It takes a downward spiral direction round the crus cerebri, being at first directed backwards, then outwards and forwards,

and terminating with an inclination inwards. Its floor presents a convex elevation, *hippocampus major* (*cornu Ammonis*), extending its whole length. This is the obverse of the sulcus termed hippocampal, and is separated by a groove from the posterior crus of the fornix and from the fimbria, which in turn has the choroid plexus entering at its free edge into the cornu. At its extremity the hippocampus is expanded somewhat, and has

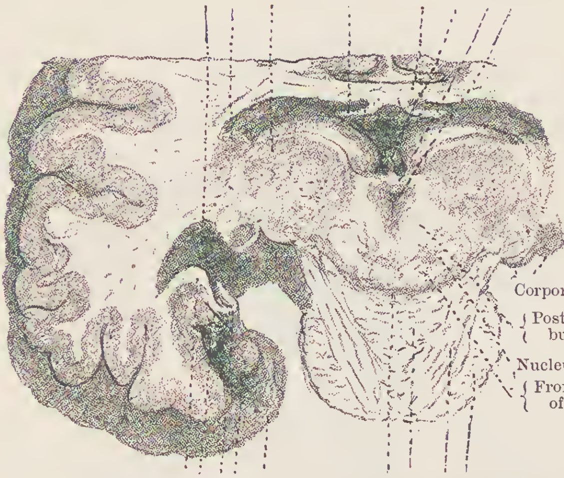


FIG. 450.—VERTICAL TRANSVERSE SECTION, cutting the superficial part of the pons, but clear of the medulla oblongata. Looking forwards.

three or four shallow notches on its convex edge, giving it a digitate appearance, whence it has received the name of *pes hippocampi*. The hippocampus major amd minor are united at their commencements; and the angle left between them as they separate is called *eminentia collateralis* or *pes accessorius*.

VI. THE CEREBRAL HEMISPHERES.

The hemisphere-vesicle of the embryo becomes developed into two parts, the *stem-part* and the *mantle* (Reichert); the former a solid mass consisting of the corpus striatum and island of Reil, and the latter all the remainder of the hemisphere.[1] The corpus striatum and hemisphere

[1] The olfactory lobe of the encephalon is not here mentioned. It is considered as part of the hemisphere by Schwalbe (1881) and Turner (1890), who include with it under the name rhinencephalon the bulbus hippocampi. Schäfer follows the course of including under that name the combined olfactory and limbic lobes; and undoubtedly if the bulbus hippocampi is to be included in the term, he is perfectly right in

are thus, as respects development, one division of the brain, the hemisphere-vesicle; and indeed the division into stem-part and mantle is so far secondary that while in reptiles, as in mammals, the corpora striata are but limited bodies at the base of a large ventricle roofed by this mantle, in birds the mantle has scarcely a separate existence, there being only a thin membrane roofing the lateral ventricle into which the corpus striatum looks; and to such an extreme is this carried that it is impossible to escape the conclusion that work done by the mantle in mammals and reptiles is done by the stem-part in birds.

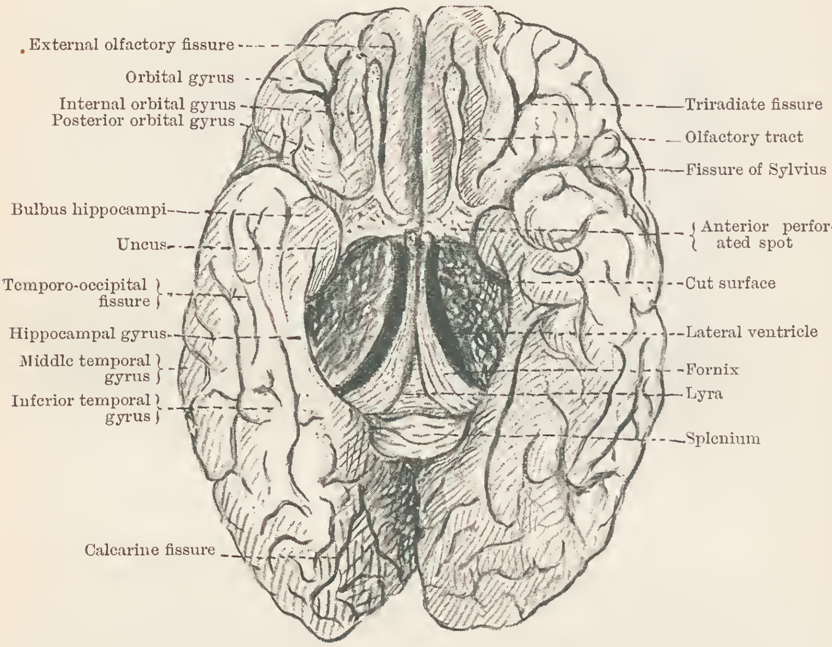


FIG. 451.—The basal surface of the hemispheres as seen after removal of the root of the brain by Reichert's section, namely, a cut carried along the outer side of the optic tract and along the furrow between the optic thalamus and nucleus caudatus.

The hemisphere, as distinguished from the hemisphere-vesicle, does not include the corpus striatum. Its grey matter is of peculiar construction,

considering that "there is no sufficient reason for excluding the remainder of the limbic lobe." Owen, who introduced the term rhinencephalon, used it to designate what he considered as one of four primary divisions of the brain, and counted as another the prosencephalon, in which he included both the hemispheres and optic thalami. The term mantle was introduced by Reichert, and is meant by Schwalbe to be used in the sense originally given to it. The whole limbic lobe, including the bulbus hippocampi, belongs to the mantle as defined by Reichert. As for the olfactory lobe, Schwalbe is right in comparing it with the retina and optic nerve, the primary optic vesicle of the embryo brain; and it might be said that in development the rhinencephalon is related to the front of the first cerebral vesicle, as the primary optic vesicle is to its back part. The rhinal fissure described by Turner in mammals is not homologous with the fissure limiting the rhinencephalon in fishes.

arranged on the surface, and is termed the *cortical substance*; and the surface is thrown into convolutions (*gyri*) and fissures (*sulci*), by which its superficies is enormously increased. The increase of surface brings the cortical substance in all its depth nearer to the supply of blood from the pia mater than would be otherwise possible, and is probably necessary for other reasons, inasmuch as there is a definite arrangement of nervous elements at different depths, just as there is in the cortical substance of the cerebellum. In no brain are the fissures and convolutions perfectly symmetrical, and in no two brains is the arrangement perfectly similar. The fissures appear in a regular order, and those which appear first are constant and symmetrical, while complication takes place by the formation of secondary and shallower fissures, and by frilling of the convolutions between. Interest attaches to the details of the arrangement, first, on account of the complexity being greater in civilized races than in savages, and greater in persons of much intelligence than in persons of little; secondly, on account of the same convolutions being found in simpler form in apes and monkeys; and, thirdly, on account of definite local paralyses or alterations of function being associated with lesions of certain definite parts of the convoluted surface, whether produced in monkeys by experiment or in men by disease.

Fig. 452.—From a Preparation in Spirit, showing the relations of the superficial convolutions to the middle meningeal artery and their positions in the head.

Convolutions and fissures. *The fissure of Sylvius.* This is no mere sulcus, but owes its existence partly to the form of the cranial cavity, partly to the fundamental division of the hemisphere into a solid part and a mantle. It begins on the base, at the anterior perforated spot, by a broad and deep part (vallecula or fossa of Sylvius), and is so situated that the free border of the orbital wing of the sphenoid fits into it. Outside the

anterior perforated spot, it contains the island of Reil, beyond which it is continued into two principal *limbs* or *branches*, viz., the *posterior*, running about two inches backwards before turning upwards a little way, and the *anterior ascending*, which is shorter and is directed upwards and a little forwards after giving off at its commencement a less important and short *anterior horizontal* branch. According to Horsley the anterior ascending limb starts opposite the upper end of the spheno-squamous suture and runs upwards along by or just in front of the coronal suture, while the anterior horizontal corresponds in position with the spheno-parietal suture, and the posterior limb, starting from opposite the highest point in the squamous suture, ends close to the parietal eminence.

The *island of Reil* (*insula*, *lobus centralis*, *gyri operti*) is a triangular mass isolated from the rest of the hemisphere by a depression, *sulcus circularis* v. *limitans*, and broken externally into *gyri breves*, typically five in number,

FIG. 453.—LEFT ISLAND OF REIL AND OLFACTORY LOBE, WITH DESCENDING CORNU OF LATERAL VENTRICLE laid open by a cut through the wall between it and the posterior branch of the fissure of Sylvius, and reflecting the floor containing the hippocampus major.

the three foremost separated by a complete sulcus from the two behind (anterior and posterior insula of Eberstaller), and all converging toward the inner angle or *pole*. The portions immediately surrounding the circular sulcus are spoken of as *opercula*. Cunningham counts four of these: (1) the external, known as *fronto-parietal*; (2) the posterior or *temporal*; (3) the *orbital*, lying internal to the anterior horizontal branch of the Sylvian fissure; and (4) the part which sometimes intervenes between the fronto-

parietal and the orbital, the *frontal* operculum; the frontal being the *pars triangularis* of the third frontal convolution, called *le cap* by Broca.

Superficial aspect. The *fissure of Rolando* (*sulcus centralis*) begins at the mesial border of the hemisphere a little behind the mid point of its upward arch, and runs downwards and forwards towards the Sylvian fissure. Its upper end shows more frequently than not on the mesial surface, to at least a slight extent and with a backward inclination. Its lower end usually falls short of the fissure of Sylvius, but points to the middle of the island of Reil. In its course, which is never direct, a backward *upper genu* and a forward *lower genu* have received attention.

The convolutions bounding the Rolandic fissure are best named *anterior* and *posterior Rolandic gyri* (Pansch), but are also known as *ascending frontal* and *parietal*, and *anterior* and *posterior ascending* or *central.* In front of the anterior Rolandic gyrus, the *precentral sulcus* (transverse frontal fissure so

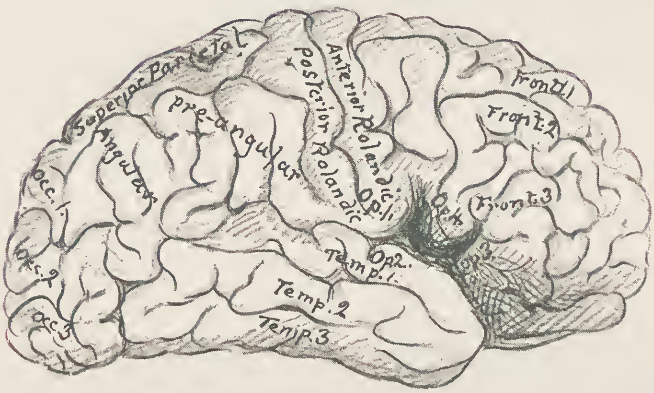


Fig. 454.—Outer Side of Right Hemisphere. Op. 1, 2, 3, 4 are the four opercula of the island of Reil, numbered as they are numbered in the text.

called) is placed, distinct below from the anterior ascending Sylvian limb, and falling short of the mesial border above. In front of this, a *superior* and an *inferior frontal* sulcus separate the *superior*, *middle* and *inferior frontal gyri.* The superior frontal is more or less continued into the anterior Rolandic gyrus, and the inferior frontal ends posteriorly in a dilated pars triangularis, *le cap* of Broca, already alluded to in connection with the opercula, remarkable as being, especially on the left side, the seat of lesion in aphasia. The three frontal convolutions constitute the *frontal lobe* of Gratiolet; but more usually the term frontal lobe is used to designate the whole surface in front of the Rolandic fissure, as recommended by Turner; and though this is topographically less appropriate, it is to be remembered that all divisions of the mantle into lobes are quite artificial and open to objection.

Behind the posterior Rolandic gyrus the *postcentral sulcus* is situated, which, like the precentral, falls short both of the mesial edge and of the Sylvian fissure; but toward the upper end it has its main continuation

turned backwards, and thus presents an *ascending* and a *horizontal* part. Above the horizontal part the *superior parietal gyrus* is placed, extending back to where the parieto-occipital, a sulcus of the mesial surface, cuts the superior edge of the hemisphere opposite the lambda, while two gyri lie below it—one in front of the other—the *supra-marginal* (or, better, *pre-angular*) and the *angular*. The convolutions further back constitute the *occipital lobe*, and are called *superior*, *middle* and *inferior occipital gyri*, and are separated by *superior* and *inferior occipital sulci*; while, in like manner, the surface below the posterior limb of the Sylvian fissure is called *temporal lobe*, and is divided by a *superior* and an *inferior temporal sulcus* into *superior*, *middle* and *inferior temporal gyri*.

The mesial and inferior surfaces. The earliest of the mere sulci of the mantle to appear is the *calloso-marginal sulcus* which, beginning below and in front of the rostrum of the corpus callosum, turns round that body and divides the mesial surface into a marginal and a callosal part. When it reaches opposite the splenium, it turns upwards and ends by cutting the superior margin just behind the fissure of Rolando. Further back, opposite the tip of the occipital bone, another, the *parieto-occipital sulcus*, begins by deeply cutting the superior margin, and is directed downwards and forwards to meet a second, the *calcarine sulcus*, named from corresponding in position with the hippocampus minor, which is its obverse; and from the point of meeting of these two a third, the *anterior calcarine sulcus*, sweeps forwards and downwards beneath the splenium. On the tentorial and sphenoidal parts of the under surface there runs forwards, parallel to the inferior temporal and occipital sulci, a line of *occipito-temporal sulci*; and between these and the anterior calcarine *sulcus* there may be another line, the *collateral sulcus*. The district between the calloso-marginal sulcus and the margin of the great longitudinal *sulcus* is termed the *marginal convolution*, and has a tendency to be more or less doubled by a longitudinal sulcus within it, a doubling which is alleged to be absent when the first frontal convolution is doubled, and present when the first frontal is single (Manouvrier). The wedge between the calcarine and parieto-occipital sulci is called the *cuneus*, the space in front of it, extending from margin to splenium, and forwards to the turning up of the calloso-marginal fissure, is the *praecuneus* or *quadrate lobule*, and the portion of the marginal convolution immediately in front of this has been called the *paracentral lobule*. The convolution traceable round the corpus callosum from front to back of the anterior perforated spot is the long known *gyrus fornicatus* or *gyrus cinguli* (limbic lobe of Broca). The name *callosal gyrus* is best confined to the part over and in front of the corpus callosum, and to this part the term gyrus fornicatus also is by some recent authors restricted, while the posterior part turning round the crus cerebri is the *gyrus hippocampi*, slightly dilated at its extremity in man, but much more so in animals with well developed smell, to form the *bulbus hippocampi*. The dilatation presents an inward fold, the *uncus*; also a thickening of the cortex, sometimes called *nucleus amygdalae*. The

fissure between the main gyrus and the uncus corresponds with the pes hippocampi, and is continuous with the *sulcus hippocampi*, the obverse of the hippocampus major. The sulcus hippocampi separates the inner margin of the gyrus hippocampi from the *gyrus dentatus* (fascia dentata), a thin streak of grey matter indented by small bloodvessels, and intervening between the gyrus hippocampi and the fimbria.

FIG. 455.—RIGHT HIPPOCAMPUS MAJOR removed with temporo-sphenoidal lobe.

Resting on the anterior fossa basis cranii are the orbital convolutions and sulci, constituting the *orbital lobe* (Gratiolet). Parallel to the great longitudinal fissure there is a constant sulcus against which the olfactory tract and bulb lie, the *olfactory sulcus*, with the *gyrus rectus* on its inner side; and in the middle of the surface external to it there is a sulcus with three ramifying branches, *triradiate sulcus* (Turner). The convolutions separated by the three branches have been variously described and are subject to much variation, but may be best distinguished as the *external* and *internal orbital*, more or less sagittal, and the *posterior orbital*, transverse in direction.

Structure. A vertical section through the cortical substance of the hemisphere in the unaltered condition shows everywhere a division into a superficial reddish-grey stratum and a deeper stratum of colder grey tint, separated from the other by a thin whiter line, the *primary pale band*. In some parts of the hemisphere a deeper pale band can be easily seen, which does not, however, arise from additional complexity, but rather the reverse; and it is noteworthy that in the occipital lobe, where the deeper or second pale band is best seen, the total depth of cortical substance is least.

Beginning at the pia-matral surface, there is found most superficially, in some parts, a certain number of medullated fibres; and these are so numerous on the gyrus hippocampi as to give a visible milky covering called *reticulated white substance*, while in other places they are altogether absent. They may be counted as belonging to the most *superficial* layer everywhere present, the *superficial molecular layer*, in which there are numerous neuroglial spider-cells, and great numbers of exceedingly fine nerve-fibres of two sets, one

lying horizontally with minute nerve-corpuscles of more than one shape connected with them, and the other branching toward the surface from deeper strata. In the deeper part of this stratum there is great abundance of nuclei, or small corpuscles with little or no proper corpuscular substance round them, and from them we pass to what are usually counted the *second* and *third* layers, namely, those characterized respectively by *small* and *large pyramidal* corpuscles, which, however, graduate regularly one into the other, the smallest pyramids being most superficial, and the largest the deepest. Then comes the primary pale band, and beneath it the *fourth* layer, or layer of *polymorphous* nerve-corpuscles of various authors. The primary pale band presents a second stratum rich in nuclei (Cleland, 1870), and beneath it a stratum of horizontally placed medullated fibres. The layer of polymorphous corpuscles has in it both nuclei and pyramidal corpuscles, though more irregularly arranged than in the more superficial strata, and among other kinds a larger number of fusiform nerve-corpuscles, both vertical to the surface and parallel to it, and also corpuscles with an ascending axis-cylinder.

Fig. 456.—Semidiagrammatic Section of Grey Matter. (J. C., 1870.)

The pyramidal corpuscles are those which are typical of the cerebral convolution. Their characteristic feature is that they are broadest at their deep end, and taper to a point like a church-spire, the point being directed toward the surface and prolonged into a long thread, the *ascending* or *apical* pole, which runs straight on, giving off in its course fine lateral branches, till it reaches the molecular layer, where it breaks into a crowd of diverging ramifications interlacing with its neighbours. Other protoplasmic poles, which immediately break up into branches, come off round the base; and an axis-cylinder-process directed downwards and continued into the white substance in the interior of the hemisphere, springs directly from the base or in connnection with one of the protoplasmic branches, and gives off while in the grey substance from six to ten ramifying collaterals.

The medullated fibres of the white centre of the hemisphere, traced into the grey substance, are at first in bundles, but soon become scattered

more uniformly, and get individually smaller, by diminution of medullary sheath. The large medullated fibres, parallel to the surface, *arciform fibres*

FIG. 457.—ELEMENTS IN SECTION OF CORTICAL GREY MATTER. A, Molecular layer; B, white substance; *a*, corpuscle with short axis-cylinder forming an extensive arborization; *b*, corpuscle with ascending axis-cylinder falling short of the molecular layer; *c*, corpuscles with ascending axis-cylinder ramifying in the molecular layer; *d*, small pyramidal corpuscle. (Cajal.)

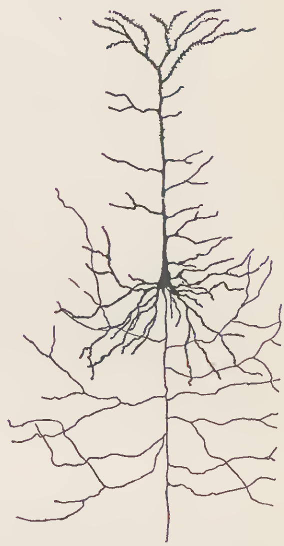


FIG. 459.—DIAGRAM OF HUMAN PYRAMIDAL CORPUSCLE, showing collaterals of axis-cylinder and branches of the corpuscle and apical pole. (Cajal.)

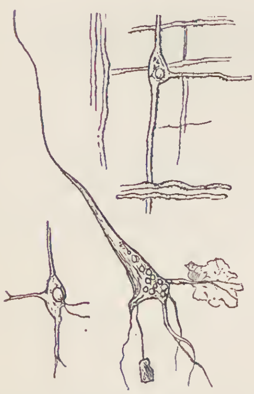


FIG. 458.—NERVE-CORPUSCLES FROM THE CONVOLUTED GREY SUBSTANCE. One typical pyramidal corpuscle with apical pole making for the surface, central axis-cylinder and lateral basal poles; and two other nerve-corpuscles of a polymorphous type with more than one axis-cylinder.

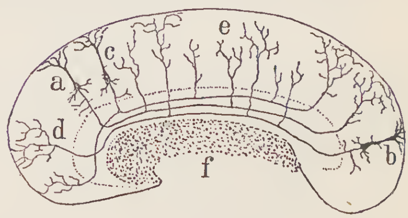


FIG. 460.—SCHEMA OF LONGITUDINAL SECTION OF BRAIN, showing disposition of the fibres of association between anterior and posterior lobes. *a*, *b*, *c*, Pyramidal corpuscles; *d*, terminal nervous arborization; *e*, ascending arborizations of collaterals of fibre of association; *f*, corpus callosum divided. (Cajal.)

of Lockhart Clarke, form a distinct layer at the deep surface of the primary white band and occur scattered more superficially, but are disposed in a

dense stratum on the deep surface of the cortical substance. They belong to the order of *association fibres*, a name used to include all bundles serving to bring into communication different parts of the hemispheres.

"Fibres come from all regions of the cortex, converging as they traverse the corpora striata to penetrate the crura cerebri. In small mammals these fibres, on arriving at the level of the corpus striatum, send out to that body a large collateral, and then descend in little bundles separated by septa of grey substance, which they provide with very fine collaterals" (Cajal).

In the grey matter bounding the sulcus hippocampi, namely, the gyrus dentatus and grey matter of the hippocampus major, there are naturally special peculiarities, as these are the parts bounding the transverse fissure, a communication with the interior caused by total suppression of the nervous wall of the hemisphere-vesicle. The pyramidal corpuscles are here gathered together into one stratum, superficial to which their ascending poles form a *stratum radiatum*, succeeded by another, the *stratum laciniosum*, distinguished by their interlacing crowds of branches; and over this the densely nucleated zone of the molecular layer is greatly developed, getting the name of *stratum granulosum.*

VII. THE OLFACTORY LOBES.

The olfactory lobes, sometimes regarded as portions of the hemispheres (p. 621, footnote), are but feebly developed in the human subject in comparison with their size in vertebrata generally and in most mammals, although it is true that in cetacea they are absent, while in the seal and in monkeys they are of smaller proportions than in man. They originate as hollow structures coming off, in elasmobranch fishes, from the sides of the hemispheres, but in other vertebrata rather from their fore and under surfaces. In most mammals they continue hollow, and in some the communication with the ventricle persists. It may further be stated here from personal observation, as indicating the place of primary union with the hemisphere, though not generally noticed, that in the human foetus so late as in the sixth month, the olfactory bulb has its sole base in front of the island of Reil, and at an earlier period is completely separated from the anterior perforated spot by a very deep sulcus filled with pia mater.

The olfactory lobe lies against the straight sulcus of the orbital surface of the hemispheres, and consists of the *bulb* and the *peduncle* or *tract*, with its *roots*.

The olfactory bulb is of oval form and grey colour; it rests on the cribriform plate of the ethmoid, into whose surface it fits, and the minute and easily torn bundles of the olfactory nerve enter its under surface. It is continued behind into a slender and white stalk, the peduncle or tract; and tract and bulb together form a structure about 1½ inches long, surrounded with pia mater. The attachment of the peduncle is at the hinder end of the sulcus olfactorius, and from it two obvious white

roots extend—an outer root directed outwards in front of the outer part of the locus perforatus anticus, and an inner root which curves inwards and turns forwards in the longitudinal fissure to join the gyrus fornicatus and peduncle of the corpus callosum. Between these two roots the grey matter continuous with the peduncle is sometimes described as the middle or grey root. In this grey matter fibres are sometimes found which apparently are developed in lower animals in a remarkable manner backwards (Rorie, *Natural History Review*, 1863). Schwalbe rightly points out that this grey surface (trigonum olfactorium) "is only the basal surface of a small ball-shaped lobule, tuber olfactorium, which occupies a deep three-sided depression at the hinder border of the under side of the frontal lobe, continuous at its base with the lamina perforata anterior, from which it is separated by a shallow groove."

In its finer structure the peduncle consists principally of white longitudinal fibres; and superficial to them a column of grey matter is prolonged from the hemisphere on the dorsal side, while in the interior a flat streak of neuroglia replaces the original hollow. The bulb presents likewise longitudinal white fibres round a central neuroglia, the white fibres gathered in small bundles with their medullary sheaths united or very closely placed. Outside the longitudinal fibres it presents dorsally only a little gelatinous grey substance, but on the ventral side it has a complex structure arranged in strata of which the deepest is characterized by angular nerve-corpuscles known as *mitral cells*, and the next by copious granules or nuclei like those of the granular layers of the cortex of the convolutions, while superficial to these is a stratum thickly strewed with globular arrangements termed *glomeruli*, and on the surface is a thick plexus of nerve-fibres continued up from the mucous membrane of the nose. These latter end in the glomeruli, each of which consists of a convoluted and branched termination of an olfactory nerve-fibre and of a complicated arborization of a protoplasmic fibre from a mitral cell. Each mitral cell has in addition other protoplasmic poles branching in the granular layer, and an axis-cylinder continued into the layer of medullated fibres.

Fig. 461.—Antero-Posterior Section of Olfactory Bulb of a Duck. a, Arborization of the olfactory fibres within the glomeruli; b, descending trunks of the large cuplike corpuscles in granular fringes within the glomeruli; c, the large cuplike or mitral corpuscles; d, superficial zone of fibres; e, superficial member of a deep zone of grainlike corpuscles. (Cajal.)

THE WEIGHT OF THE BRAIN.

Considerable attention has been devoted to the weight of the brain, for the same reasons that it has been given to the cranial capacity, namely, with a view to obtaining racial characteristics, and to ascertaining what ratio exists between mass and capability of work. So far as difference of race is concerned, cranial capacity is the easiest mode of estimating the size of the brain, since skulls can be obtained in numbers when brains cannot. On the other hand, it is weight, and not mere bulk which indicates mass. The average weight of the brain in adult males in this country has been estimated at 49½ ounces, and in women at five ounces less. The conclusion has also been arrived at that no brain under 30 ounces is sufficient for the exercise of the normal functions. On the other hand, there are instances of remarkable men having had great weight of brain. Thus Cuvier's brain, the heaviest on authentic record, weighed 65 ounces; but it is beyond doubt that neither do large brains belong exclusively to great men, nor have all great men had particularly large brains; and, apart from the sources of greatness being very various, it is to be remembered how many different parts go to make up brain-mass, that the amount of cerebral cortex does not vary *pari passu* with the brain-weight, and that, even if it did, we do not know how much depends on perfection of the systems of association-fibres.[1]

The weight of the brain varies more regularly in proportion to stature than to weight of body. The brain in the female bears a smaller proportion to the stature than it does in the male, but a greater proportion than in the male to the weight of the body. Also the ratio of the cerebrum to the cerebellum is smaller in the female than in the male, being as 7·84 to 1, instead of 8·02 to 1 (Marshall). It is a well-known law that the smaller the animal the greater the proportion, *ceteris paribus*, of the weight of the brain to that of the body: this has been found to hold good in the human subject in both sexes, and accounts for the greater proportion of brain-weight to body-weight in the female. In accordance with another law, the proportion of the brain to the rest of the body is greatest in early development. The average brain-weight of the male child at birth is about 13 ounces, and that of the female child about 12 ounces. The greatest absolute weight of brain is reached in early adult life, and appears to diminish till extreme old age.

[1] Since this account of current statements was written, there have appeared two communications in the *Lancet* on 8th and 15th June, 1895. In the first, Dr. Middlemass describes a brain weighing 65¼ oz.; and in the second, Dr J. A. Campbell gives a list of 15 brains over 60 oz. from among 1146 autopsies during a number of years in the Cumberland and Westmoreland Counties Asylum. The 15 brains included one female, 62½ oz.; the other 14 were male. The heaviest weighed 71½ oz., the next weighed 65 oz., and the next 63¼ oz., while four weighed each 62½ oz. This appears to be one of the most important contributions to statistics of heavy brains yet made, and makes one wish for further results of the 1146 autopsies, as well as for records of similar sort from other institutions.

DEVELOPMENT OF THE CEREBRO-SPINAL AXIS.

The cerebro-spinal axis, as already stated (p. 90), makes its first appearance as the epiblast of the medullary groove, and is soon converted into a cylinder by turning inwards of the margins. In the cord, while yet those margins are still in continuity with the epidermis beyond, there is a separate thickening formed in the fold of eversion on each side, and these thickenings remain in connection with the cord as ridges projecting outwards in each segment to form a pair of spinal ganglia, the sources of the sensory nerve-fibres, while the motor roots project from the cylinder

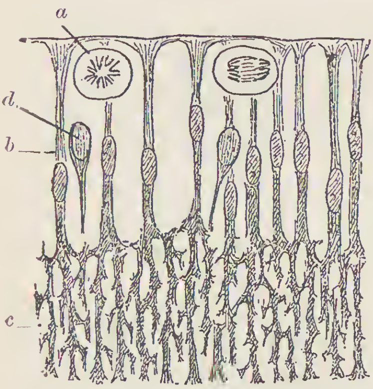


Fig. 462.—Section of Texture of Human Embryo Cord. *a*, Germinal cells between inner ends of spongioblasts; *b*, columnar part of the spongioblasts; *c*, reticular or marginal zone formed by them; *d*, neuroblast. (Cajal, after His.)

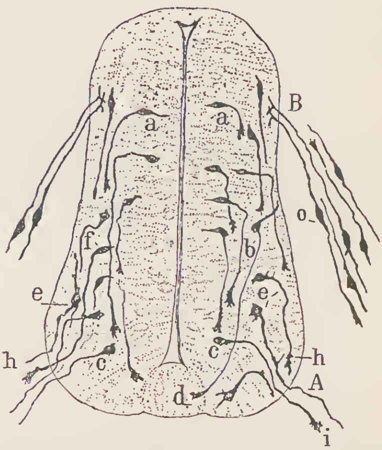


Fig. 463.—Section of Cord of Chick of Third Day of Incubation. A, Anterior root; B, posterior root; *a*, *a*, very young neuroblasts; *b′*, a more developed neuroblast, probably commissural; *c*, *c*, neuroblasts of anterior roots; *d*, growth-cone of a commisural axis-cylinder; *e*, *e′*, corpuscles of anterior nerve-roots, already with rudimentary dendrites; *h*, *i*, growth-cones of anterior roots; *o*, corpuscles of spinal ganglion. (Cajal.)

in a more ventral position corresponding with their subsequent site of origin. The epiblast in the open medullary groove already consists of columnar epithelial cells whose deep extremities alternate with others; and after closure of the cylinder it thickens on each side, leaving the central canal linear in transverse section and bounded ventrally and dorsally by short cells. The lateral thickening is effected by elongation of the columnar cells or *spongioblasts*, and prolongation of each into branches which unite with similar branches of others to make a reticulum extending to the mesoblastic surface. This is the *myelospongium* of His, destined to form at least the foundation of the neuroglia. Between the columnar cells, close to the central canal, there are *germinal cells* in different stages of karyokinesis, giving rise, according to His, to the *neuroblasts*, cells with a large oval nucleus and an elongated process directed towards the place of emergence of the anterior root. By means of the chromate of silver method

the axis-cylinders of the motor nerves have been seen in embryonic animals pushing their way through the tissues with a little *growth-cone* at their extremity, and the sensory nerves have been seen growing outwards and inwards from their spinal ganglia. Within the cord the most ventral neuroblasts send their growth-cone into the anterior root of the same side, the most dorsally situate push theirs across the middle line at the anterior commissure, while others intervening insinuate theirs into the periphery of the cord, the region of the future white columns. By the sixth week, in the human subject, the central canal projects dorsally considerably beyond the posterior roots, and laterally opposite them; the posterior columns are distinctly seen on each side, and the anterior columns project ventrally on each side of the middle line, separated by the first indication of the anterior longitudinal fissure.

Till the foetus is four inches long from crown to nates, the cord and vertebral column grow equally, the nerves being given off opposite the intervertebral foramina by which they emerge, and the length of the canal being occupied. After that period the cord lengthens more slowly than the column, and by the time of birth it terminates opposite the third lumbar vertebra. Obviously this entails more rapid and greater growth of the lower nerve-roots to form the cauda equina; but it is interesting to note that other nerve-roots have been found equal to effecting a similar elongation without the aid of heredity, when it has been forced on them by displacement of the brain in hernia cerebri.[1]

The development of the brain has been already to some extent referred to (pp. 90 and 97). It originates in the part of the medullary groove first laid down, and soon takes the form of a series of three *primary cerebral vesicles*, the third or hindermost of which elongates and tapers to the cord, while the second is at first of oval form, and the first or foremost expands in a trilobate fashion. The lateral lobes of this trilobate expansion each become quickly marked off in the shape of a globular part and a pedicle, the *primary optic vesicle* and the *optic nerve*; and in the chick in the first half of the second day of hatching, the grooves bounding the inner margins of the pedicles meet in the middle line exactly in the constriction between the first and second cerebral vesicles, which is therefore the precise site of the anterior edge of the optic commissure, a fact too little taken into account in judging of the morphological relation of the eyeball to the second cerebral vesicle (Fig. 96 A). Immediately afterwards the first cerebral vesicle of the chick becomes bifid at its extremity, this bifidity being the earliest indication of hemisphere-vesicles (Fig. 96 B). While these changes have been taking place, the brain has become more and more bent on itself by the greater growth on the dorsal than on the ventral side, so that the direction of the first cerebral vesicle is reversed and has its distal end pointing downwards.

The third primary cerebral vesicle, the after-brain, early shows a division

[1] Cleland, *Journal of Anatomy and Physiology*, April, 1883.

laterally into compartments, more or less vaguely delineated in old works, beginning with those of Malpighi. These compartments in the chick are of a very constant description (J. C., *Nature*, 1875), being at first distinctly five in number, with the auditory pit appearing opposite the constriction between the fourth and the fifth (Fig. 98). In the fourth day they assume the form of deep recesses, which soon after become filled up, and their future history remains to be worked out. Very soon there becomes apparent in the roof of the third vesicle a deficiency in the neural cylinders, free edges being visible along the sides. But from the foremost (proserial) extremity a backward growth sets in, with a free edge directed backwards, and this is the commencement of the cerebellum, which afterwards becomes prominent and has its dorsal substance so redundant that the free edge is turned round by it, remaining through life as the posterior velum. On

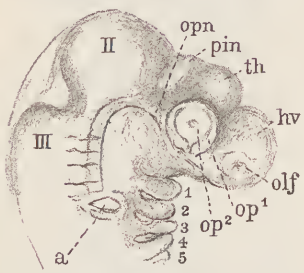


FIG. 464.—HEAD OF EMBRYO CHICK OF THIRD DAY. 1, 2, 3, 4, 5, Visceral lobes; *II*, *III*, second and third primary cerebral vesicles; *a*, auditory pit, between fourth and fifth lateral compartments of third vesicle; *op*¹, primary optic vesicle; *op*², secondary optic vesicle; *opn*, optic tract and nerve; *pin*, pineal body; *th*, thalamencephalon; *hv*, hemisphere-vesicle; *olf*, olfactory pit.

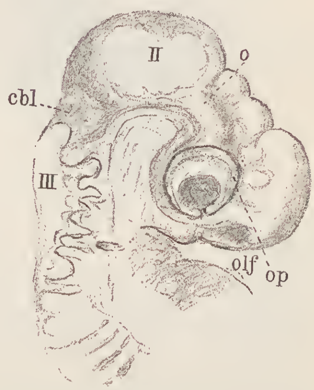


FIG. 465.—HEAD OF EMBRYO CHICK OF FOUR DAYS. *cbl*, cerebellum; other letters as in last figure.

each side behind the cerebellum there is a deep lateral cleft, in front of the first of the original five compartments. This is seen to advantage in the human foetus of about four months, and round its edges a membranous growth rises up, which is the commencement of the flocculus. While therefore the cerebellum is a mesial dorsal growth, the flocculus is ventro-lateral and starts from a more retroserial position. The ligula is also seen to advantage in the young foetus, and easily recognized as an imperfect dorsal wall of the lower half of the fourth ventricle. Two antero-posterior curves are early seen in the third vesicle, namely, a ventral convexity, on the sides of which the floccular clefts and growths are placed, and a dorsal convexity corresponding in position with the point where the clavae separate and the medulla oblongata becomes open.

The second cerebral vesicle, or middle brain, is the source of the corpora quadrigemina and other parts around the aqueduct of Sylvius. In the embryo chick it becomes greatly distended, remaining for a considerable time the most elevated part of the brain. In the mammal it takes the form

of a narrower tube bent over on itself. In the process of bending, however, in this region, the optic commissure is carried with the optic thalami downwards, which gives a seeming justification to the generally received view that optic tracts, optic commissure, and primary optic vesicles belong to quite a different part of the brain from the corpora quadrigemina. However, it will be noted, both in the chick and in His's figure of the human brain of four and a half weeks, that the anterior or upper border of the optic tract is marked out by a deep depression.

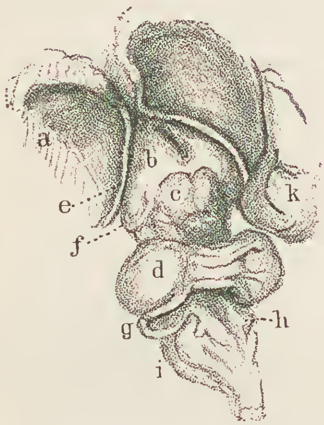


FIG. 466.—FROM FOETUS OF FOUR MONTHS. *a*, Corpus striatum; *b*, optic thalamus; *c*, corpora quadrigemina; *d*, cerebellum; *e*, stria terminalis; *f*, external geniculate body; *g*, flocculus; *h*, ligule; *i*, olivary body; *k*, cuneus.

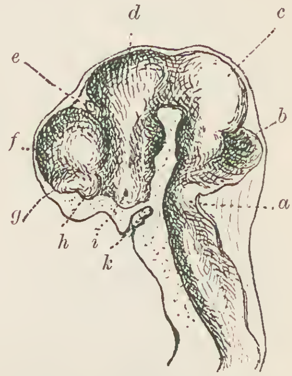


FIG. 467.—BRAIN OF HUMAN EMBRYO OF $4\frac{1}{2}$ WEEKS. Profile view. *a*, Peduncle of flocculus; *b*, cerebellum; *c*, corpora quadrigemina; *d*, optic thalamus; *e*, pineal body; *f*, hemisphere; *g*, *h*, anterior and posterior olfactory lobes; *i*, optic nerve; *k*, hypophyseal pouch. (After His.)

The first cerebral vesicle, apart from the primary optic vesicles, is the source of the region of the third ventricle, thalamencephalon and hemisphere-vesicles, together called fore brain or *prosencephalon*, and of the olfactory bulbs or rhinencephalon. The hemisphere-vesicles, beginning as a pair of projections from the extremity of the undivided thalamencephalon, sprout forwards, and are then directed upwards and backwards over it, so that in a foetus of twelve weeks (Fig. 428) they not only cover it dorsally and laterally, but overhang the corpora quadrigemina. The corpus striatum, together with the insula, is a development of the ventral root-part of the hemisphere-vesicle. The original neck of communication between the hemisphere-vesicle and the thalamencephalon is called *primitive foramen of Monro*, and is identical with the foramen of Monro in the adult. Backwards from it, in consequence of the great growth of communicating substance between optic thalamus and corpus striatum, there is a change of form which ultimately simulates adhesion of the two structures, but it may be noted that in a foetus of four months there is a very deep cleft between optic thalamus and corpus striatum. Above this, on a line back from the foramen of Monro, there is a tract of non-development of neural elements on the dorsal and posterior aspects of the neck of the hemisphere-

vesicle, while in the same position there is hypertrophy of the folded pia mater. Thus the hypertrophied pia mater occupies a groove in the inner wall of the hemisphere-vesicle, and being separated from the cavity by nothing but a layer of epithelium, becomes the choroid plexus of the lateral ventricle.

The olfactory lobe springs early, as a hollow outgrowth, from the anterior inferior part of the hemisphere, and in a human embryo of four and a half weeks has been figured by His as already showing indication of an anterior and a posterior part. In the third and subsequent months, it can easily be seen, as figured by Tiedemann, on the inner and back part of the orbital lobe of the hemisphere and extending forwards free to form peduncle and bulb, while from the base, which contains the original communication with the interior of the hemisphere, a thick elevation strikes directly outwards in front of the island of Reil.

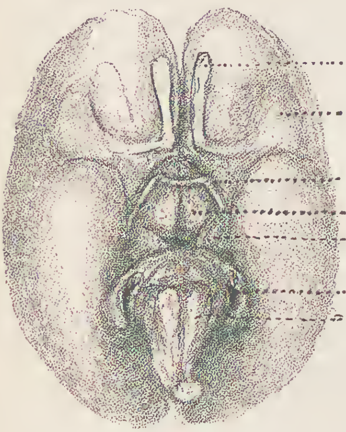


FIG. 468.—BASE OF BRAIN OF FOETUS OF FOUR MONTHS. $\frac{4}{3}$.

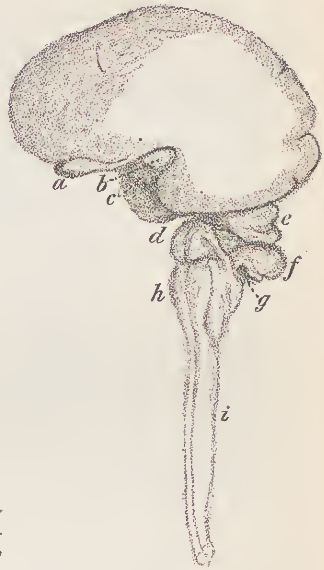


FIG. 469.—BRAIN OF FOETUS OF THREE MONTHS, $\frac{3}{2}$. *a*, Olfactory bulb; *b*, insula; *c*, corpora albicantia; *d*, pons; *e*, corpora quadrigemina; *f*, cerebellum; *g*, floccular notch; *h*, anterior pyramids; *i*, cervical enlargment. Transitory fissures are seen on hemispheres.

FIG. 469.

The thalamencephalon is originally completely roofed, and in the chick of the fourth day presents a pointed mesial dorsal projection apparently attached to the roof of the containing parietes. This is the pineal body, whose connections no doubt turn it back at the same time that the falx cerebri, which was originally vertical and in front of the corpora quadrigemina, is flung backwards by the enlargement of the hemispheres. The development of the pituitary body has been already referred to in connection with its structure (p. 612), and with the development of the base of the skull (p. 245). The corpora albicantia are remarkable in being very largely developed in the fourth and fifth month of foetal life, so as to form a great rounded eminence not altogether behind the chiasma, but extending beyond its anterior edge.

The surface of the hemispheres in the third month exhibits a number of *transitory fissures*; and in the fourth and fifth months a certain number of these are still seen lying transversely in the neighbourhood of the upper and inner border, especially about the middle. It is especially noticeable that there are in the interior of the lateral ventricles of the young foetal brain elevations, the obverses of fissures, which do not occur later. The fornix owes its origin to a pair of *choroidal fissures*, which at first are of the nature of other sulci; and although the nervous wall gives way, and the pia mater plunges into the ventricular space, it is to be recollected that the lining epithelium is not interrupted. Higher up than the choroidal fissure, while as yet there is no corpus callosum, an extensive longitudinal sulcus, *fissura arcuata*, begins in front of the olfactory bulb, its obverse appearing as a great convexity on the mesial wall of the fore part of the lateral ventricle, and arching backwards. Its fore part persists as the callosal fissure, and its hinder part as the hippocampal and calcarine fissures, the latter being one of a series of radiating offsets, the rest of which are transitory, with the exception of the occipito-parietal.

The corpus callosum seems to begin in close connection with the anterior white commissure, but becomes separated from it and the adherent lateral halves of the fornix by a depression deepening backwards to form the fifth ventricle, which is ultimately closed off from the peripheral surface.

ORGANS OF SPECIAL SENSE.

The organs of common sensation, scattered over the body, and consisting of mere nerve-extremities and minute structures connected with them, have been relegated to General Anatomy (p. 78).

The organs of special sense are of two very different kinds, the organ of taste being in no respect homologous with the others.

Taste is dependent on nerve-terminations scattered over a portion of mucous membrane supplied with sensation by two pairs of cranial nerves, both of them distributed to other parts as well, and is only a function of the tongue, an organ belonging anatomically to the digestive system.

But the organs of smell, sight, and hearing are in many respects serially homologous structures. They are closely connected with three pairs of outgrowths of the brain, viz., the olfactory bulbs, the primary optic vesicles and the flocculi. They each present an invagination of the cutaneous surface. Each has, closely connected with it, a communication between the mucous membrane and the surface of the body; and, lastly, it may be added, though only as an opinion, that there is proof from comparative anatomy that their nerves emerge through openings in serially homologous elements of the cranium.

The sense of smell, however, is in respect of simplicity, comparable with taste; while the appreciation of variations of light and sound necessitates much complexity in the eye and ear.

THE NOSE.

Under this name is included the whole extent of the nasal fossae, which open in front by the nostrils, and behind into the pharynx, bounded in front by the nasal cartilages, and having air sinuses in connection with them. In fishes, the myxinoids excepted, the olfactory organ is distinct from the alimentary canal, and devoid of communication therewith. But in all air-breathing vertebrata, posterior nares exist, and odours are conveyed to the termination of the olfactory nerve by inspiration. Thus, the lower part of the nasal fossae are subservient to the sense of smell, but belong also to the respiratory tract; and, in vocalization, which is equally dependent on respiration, the voice is modified by vibration throughout the nasal fossae and the air-cavities connected with them.

The nasal cartilages complete the septum between the nasal fossae, and shut them in anteriorly: they are mesial and lateral. The *mesial* or *septal cartilage* is the persistent extremity of the cartilaginous primordial cranium, which was continued forwards in early life from the front of the body of the sphenoid bone, invaded above by the central plate of the ethmoid, and sheathed below by the vomer and the crista nasalis. Owing to the irregular development of the vomer, its posterior connections vary somewhat in the adult, vestiges being still traceable in many instances back to the sphenoid, with a vomerine ala on one side or on both; but it fits edge to edge, in direct continuity with the central plate of the ethmoid forward to the nasals, while from nasals, vomer and maxillaries it is separated by fibrous tissue, and its inferior border is prolonged forwards between the nostrils, where it can be felt turning upwards near the tip of the nose. The anterior border of the septal cartilage is continuous at one part with the mesial edges of the *triangular* (*upper lateral*) *cartilages*, two plates which, united in the middle line, extend outwards and adhere by their upper edges to the margins of the nasal bones, while their lower edges are slightly separated from the alar cartilages. The *alar* (*lower lateral*) *cartilages* present each an expansion limiting the nostril in front, and giving shape to the extremity of the nose. From the inner side of this expansion a linear band passes backwards in the *columella* or strip of integument between the nostrils, and may end in a prominence inside the nostril; and on the outer side the expanded part may be prolonged

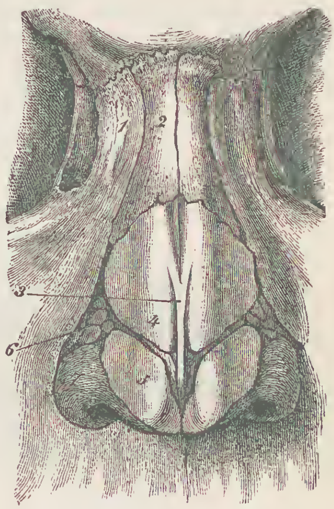


FIG. 470.—NASAL CARTILAGES. 1, Maxillary; 2, nasal bone; 3, septal cartilage; 4, triangular cartilage; 5, alar cartilage; 6, accessory cartilage; 7, adipose tissue. (Luschka.)

back in a thinner and narrower form for some distance on the lateral dilatation of the wall of the nostril, called the *ala*. Sometimes portions of this prolongation are completely detached. Other little detached *accessory cartilages* occur between the alar and the septal cartilage. The greater part of the ala of the nose contains no cartilage.

The nasal fossae, so far as their extent and the form of their walls are concerned, require no further description than has been already given at p. 238; for they are lined in their whole extent with mucous membrane closely adherent to the periosteum and extending round the cavities of all the various air-sinuses. This used to be called the pituitary or the *Schneiderian* membrane. It is thick and spongy over the turbinations of the ethmoid (*superior* and *middle concha*) and on the septum nasi, still more so on the inferior turbinated bones (*inferior concha*), but comparatively thin and firm on the floor and other boundaries, and reduced to tenuity within the air-sinuses. It is divisible into three districts, namely, the vestibule and the respiratory and olfactory tracts.

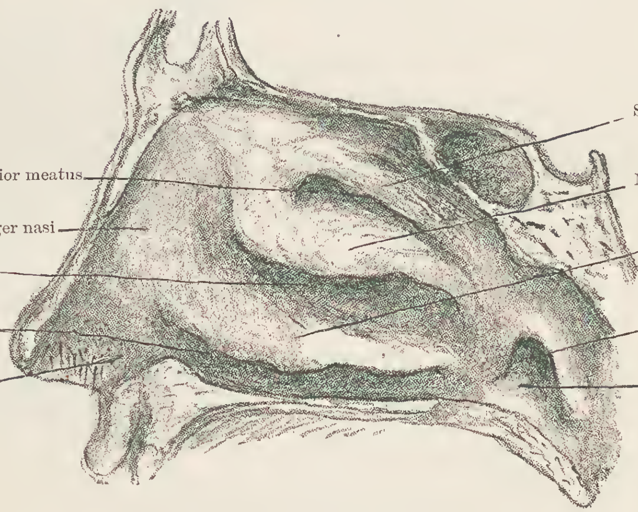


Fig. 471.—Outer Wall of Right Nasal Fossa.

The *vestibule* is the part in front, where the cavity is roofed in by the nasal cartilages, and is lined with stratified squamous epithelium. Close to the apertures of the nostrils it presents large sebaceous glands and hairs projecting into the passage.

The *respiratory tract* includes the whole nasal fossa, with the exception of the olfactory tract to be described over the vestibule. It has stratified ciliated columnar epithelium, as have also the air-sinuses, and is studded over with the racemose glands. It abounds in lymphoid tissue more or less diffuse, and in leucocytes which make their way even to the surface. The part in front of the inferior turbinated bone and inferior turbination of the ethmoid is called the *agger nasi*.

The olfactory tract has usually been described as coextensive with the turbinations and mesial plate of the ethmoid, but Max Schultze declared it to be limited to the level of the upper turbination, and the researches of v. Brunn have now made it certain that both the olfactory nerve and the olfactory part of the mucous membrane are confined to one continuous district, situated on the upper ethmoidal turbination without reaching either its lower edge or posterior extremity, and extending across the roof down over a similar area on the septum, the whole olfactory tract of both fossae being little more than a square inch in size. It has a non-ciliated columnar epithelium, which presents, besides deep cells, two sets of elongated cells stretching down through it; one, the proper columnar epithelial cells, are prolonged deeply in long dividing branches continuous with the stroma beneath; the other, the *olfactory cells*, are attenuated rod-like structures between the larger columnar cells, with their nuclei mostly placed more deeply, and receive their name from their deep extremities being supposed to be continuous with olfactory nerve-fibres, as has now been finally demonstrated to be really the case. V. Brunn has distinctly made out in the human subject, what had been seen in the frog and other animals, numbers of hair-like processes surrmounting the olfactory cells. He demonstrates also the existence of a delicate membrane, with apertures through which the hair-like processes project (*external limiting membrane*). The glands of the olfactory region (glands of Bowman) are tubes with dilated extremities and a tendency to convolution. In the human subject several are gathered to one outlet (Toldt), and the epithelium is cylindrical. The branches of the olfactory nerve, after piercing the cribriform plate of the ethmoid, are arranged in a close network of branches. The nerve-fibres are non-medullated axis-cylinders, with nucleated primitive sheaths. As they approach the surface they break up into minute fibrils.

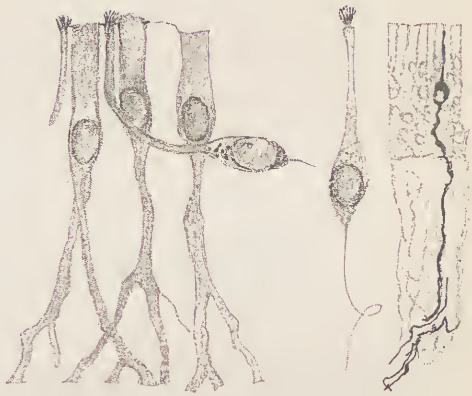


FIG. 472.—OLFACTORY CELLS. *a*, Three epithelial cells, an olfactory cell and the peripheral process of another. A membrana limitans unites the free extremities of the cells; the olfactory cells are surmounted by olfactory hairs, and the middle epithelial cell by a structureless cap; *b*, olfactory cell with deep process followed further; *c*, an olfactory cell prepared by the Golgi method. (v. Brunn.)

The nasal fossae are supplied with blood, in the upper part by anterior and posterior ethmoidal branches of the nasal artery, and lower down by branches of the internal maxillary artery. They receive branches from Meckel's ganglion and, anteriorly, offsets from the nasal branch of the ophthalmic division of the fifth nerve.

Development. The first appearance of the olfactory organ is an epiblastic depression, which is afterwards inclosed by the development of the face, and complicated by the ethmoidal turbinations.

Jacobson's organ, a structure developed in most mammals, and traced in other vertebrates, exists in vestigial form in the human subject, but will be best understood by referring first to the ruminant form which Jacobson described. If a probe be passed through the patent incisor foramen in the palate of a sheep or goat, and a vertical section be made on the same side, the probe will not be visible in the nasal cavity, because it will have entered a compressed pouch whose mouth is close to the incisor foramen, and which extends backwards within a cartilaginous sheath derived from the septal cartilage, and concealed by the

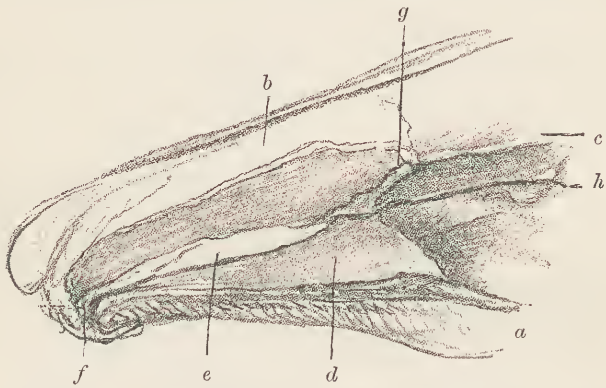


FIG. 473.—JACOBSON'S ORGAN of right side of nose of goat. *a*, Right side of palate; *b*, septal cartilage; *c*, central plate of ethmoid; *d*, deep side of mucous membrane of mesial wall of right nasal fossa; *e*, cartilaginous capsule containing the mucous membrane of Jacobson's organ; *f*, mouth of capsule in the incisor foramen; *g*, olfactory branch to Jacobson's organ; *h*, the branch from Meckel's ganglion.

mucous membrane of the septum. Passing forwards to it are two long and distinct nerves, one from the olfactory and the other from Meckel's ganglion; and the mucous membrane has been found to present olfactory cells continuous with nerve-fibres, like those of the nasal cavity (v. Brunn). This organ first found in the human subject in the foetus (Dursy), was discovered by Kölliker to be generally present in the adult as a minute pouch, about an eighth of an inch long, lined with ciliated epithelium. The cartilage is also faintly represented.

THE EYE.

The essential part of the eye is the eyeball, containing within it the nerve-terminations sensitive to light, the refractive apparatus by which the landscape is repeated on the sensitive surface, and arrangements for regulating focus; while it is bounded in greater part by a fibrous capsule, the *sclerotic*, and completed in front by a transparent structure, the *cornea.*

The eyeballs are surrounded by muscles already described (p. 334), which come into use by turning the antero-posterior diameters or axes of vision of the two eyeballs on one object, either directly in front, or above, below or toward one side. In addition to all these structures there are others in front of the eyeballs, viz., the eyebrows, eyelids, conjunctiva and lachrymal apparatus, collectively termed *tutamina oculi*, as affording protection from glare and from violence, and preserving the necessary transparency of the surface which admits the light.

Tutamina.

The eyebrows can scarcely be considered important for the protection of the eyes, but they are present in all races of men and represented among animals, and peculiarities presented by them are frequently transmitted hereditarily. It may be noted that they consist each of an outer and an inner portion, which do not always exactly meet, end to end.

The eyelids have the integument thin, and the subcutaneous connective tissue loose and devoid of fat, enabling them to be separated easily. Beneath the subcutaneous connective tissue is a thin sheet of muscular fibres belonging to the orbicularis palpebrarum; and between this and the mucous membrane or conjunctiva of each lid, the margin is made stiff by the tarsus. The *tarsi*, or *tarsal plates*, have a cartilaginous density, but are really two fibro-plates composed of felted tissue; that of the lower eyelid is a narrow linear strip, while that of the upper lid is crescentic, fully quarter of an inch deep in the middle, and can easily be brought into view in outline in the living subject, as by its stiffness and definite upper margin it enables the lid to be everted by the surgeon. To its upper margin is attached the tendon of the levator palpebrae muscle. Both tarsi are attached at the inner extremity to the tendo palpebrarum (p. 330). In both eyelids unstriped muscular fibres extend in a thin sheet towards the orbit from the deep margin of the tarsus (H. Müller's muscle). The extremities of the aperture between the eyelids are termed the *outer* and *inner canthi*. The outer canthus is a simple angular junction of the lids, but the inner canthus is a rounded recess floored by a pink and spongy *caruncula*, and with margins each of which joins the margin of the corresponding lid at a projecting angle. These projections are the upper and lower *papilla lachrymalis*; and each of them presents an orifice, *punctum lachrymale*, directed backwards towards the eye. Along their free margins, external to the puncta lachrymalia, the eyelids are furnished with eyelashes. The eyelashes (*cilia*) are in healthy individuals curved, with their convexities toward the opposed range, and are larger in the upper than in the lower lid, and twice as numerous. Tubular modified sweat glands lie in a row behind the roots of the lashes and open in connection with their follicles. But much larger and obvious to the naked eye are the *Meibomian follicles* whose orifices lie in a single row

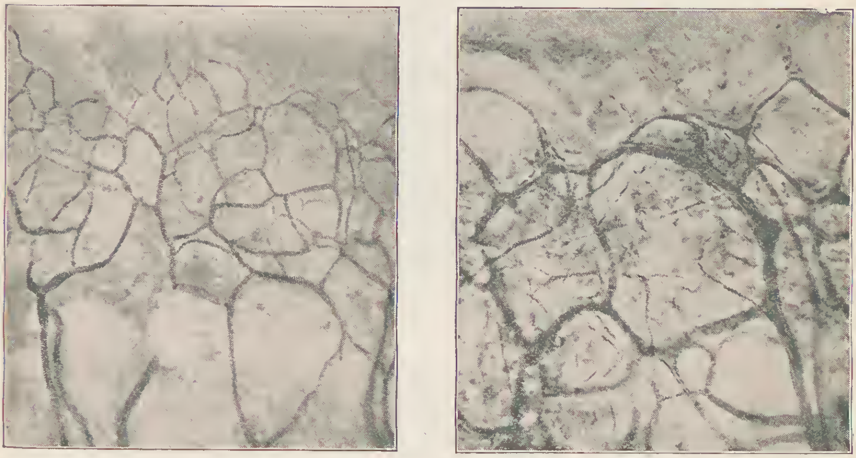
close to the inner edge of the margin of each lid. These glands can be detected through the conjunctiva, close beneath which they lie, embedded in the tarsus (Fig. 272). Each consists of a long duct with saccules, simple and divided, ranged along each side, filled with sebaceous secretion, and presenting flat secreting cells like those of ordinary sebaceous glands. They are about thirty or forty in number, and afford a certain protection against overflow of tears. The Meibomian follicles are surmounted by *accessory lachrymal* glands, consisting of convoluted masses of tubules pouring their secretion out on the conjunctiva.

FIG. 474.—*A*, ACCESSORY LACHRYMAL GLAND SURMOUNTING *B*, THE EXTREMITY OF A MEIBOMIAN FOLLICLE. (Dr. Reid.)

FIG. 475.—LYMPHATICS OF CONJUNCTIVA. *A*, Fine network with free edge on margin of cornea; *B*, over the sclerotic. (Teichmann.)

The conjunctiva is the mucous membrane within the aperture of the eyelids, developed by reflection of the integuments, and presenting a palpebral and an ocular part. The *conjunctiva palpebralis* is so vascular as to have a pink colour; it is firmly adherent to the tarsal cartilages, but beyond these is loose and easily separated. At the inner canthus it forms the *caruncle*, in which are to be found modified sudoriparous and sebaceous glands; and outside this it is thrown into a vertical fold, *plica semilunaris*, a vestigial third eyelid, better developed in various mammals, in some of which it contains tough structure, and even, as in the seal, a considerable cartilage, and also corresponding with the large membrana nictitans of birds. The *conjunctiva bulbi* is reflected on the sclerotic, and in the healthy state is transparent, displaying the course of only a few vessels, while its capillaries are insufficient to modify the whiteness of the sclerotic beneath it. Its

vessels are independent of those of the sclerotic, and form a capillary network which only slightly incroaches over the margin of the cornea, but does so by a marginal fringe of small meshes accompanied by nerves; and in the same situation the lymphatics also cease, after forming a close meshwork of finer capillaries than those of the sclerotic conjunctiva. Beyond this, the dermal elements are lost, and only the epithelium is continued over the surface of the cornea in health, although, under inflammatory irritation, conjunctival bloodvessels may spread freely on it.



A B

FIG. 476.—FREE MARGIN OF NETWORK OF CAPILLARIES OVER MARGIN OF CORNEA, photographed from stained specimen. A, Shows the breadth of the closely meshed zone, $\frac{30}{1}$; B, a portion of the same, $\frac{70}{1}$, shows the nervous plexus.

The lachrymal apparatus consists of the lachrymal gland, which secretes the tears and pours them out on the surface of the conjunctiva to keep it moist and the corneal epithelium transparent, and of an arrangement of passages, the lachrymal canals, which take up the tears from the surface of the eye, and in ordinary circumstances convey into the nose the whole amount secreted. The *lachrymal gland* occupies the fovea lachrymalis of the frontal bone, at the upper, outer and fore part of the orbit. Its length transversely is about three quarters of an inch, its breadth from before backwards about quarter of an inch, and its depth about an eighth of an inch, and it has in addition a thin outlying part in front. It pours out its secretion by about a dozen ducts, which open into the line of reflection from the palpebral to the ocular conjunctiva. It is a racemose gland, with structure similar to a serous salivary gland. It has a special lachrymal branch from the ophthalmic artery and from the ophthalmic division of the fifth nerve. Branching nerve-fibres have recently been seen in the guinea pig piercing the membrana propria and forming fine plexuses surrounding each secreting cell (Dogiel). The *lachrymal canals* or passages begin at the *punctum lachrymale* on the margin of each eyelid. From the

punctum of each lid a *canaliculus* is directed vertically for about a twelfth of an inch. The canaliculi abruptly turn to run inwards above and below the canthus, and open close together or by a single opening into the lachrymal sac, behind the attachment of the tendo palpebrarum.

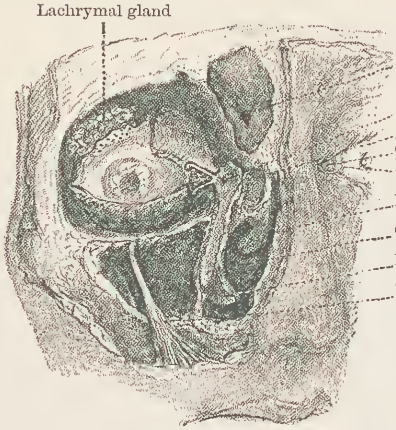


FIG. 477.—LACHRYMAL APPARATUS. The nasal fossa and the frontal and maxillary sinuses are laid open.

The *lachrymal sac* occupies the groove formed by the lachrymal bone and nasal process of the maxilla, and its fine mucous membrane is supported internally by periosteum, and externally by fibres continued from the periosteum of the margin of the groove. It is supported also by the tensor tarsi muscle passing forwards across it. It is continued inferiorly into the *nasal duct*, in which the mucous membrane adheres to the periosteum till it reaches the nasal fossa at the fore part of the inferior meatus. There the mucous membrane is slightly redundant and may offer resistance to catheterization, if not lightly handled. In the canaliculi and the lower end of the nasal duct the epithelium is stratified squamous; in the intervening sac and greater part of the nasal duct it is simple columnar ciliated.

THE EYEBALL.

The eyeball is a nearly spherical structure, the surroundings of which, including its muscles and movements, have been already considered (p. 334). The diameter perpendicular to the centre of the cornea or transparent part in front is called the *axis of vision*; and the vertical plane passing through the centre, at right angles to the axis, is called the equator. The equator is circular and about an inch in diameter; the axis of vision is somewhat shorter; and the fore part of the circumference, formed by the cornea, has the curve of a smaller sphere than the remainder formed by the sclerotic. Within the sclerotic and cornea, which together constitute the outer coat, is the middle coat or *tunica vasculosa*, consisting of *choroid*, *ciliary muscle*, *ciliary processes* and *iris*, and inside this the nervous

coat or *retina*; while the cavity of the globe is filled with transparent media, the more consistent of them, viz., the *crystalline lens* and the *vitreous humour*, occupying the greater part, but leaving in front a space called the *anterior chamber*, containing a watery fluid, the *aqueous humour*.

The sclerotic is a dense and tough white fibrous coat forming the outer wall of the eyeball in its whole extent, except for an area in front, half an inch in diameter, where it is replaced by the cornea. Its fibres are closely matted, neither confined to one direction nor one plane; and among the white fibrous bundles yellow-elastic fibres are scattered. It is incapable of stretching by sudden distension, but yields perceptibly to continued pathological pressure from within. It is thickest behind where it is about $\frac{1}{20}$th inch thick, and diminishes gradually to half this thickness about a tenth of an inch from the corneal margin, becoming perceptibly thicker close to the cornea. Posteriorly it is pierced by the optic nerve, the bundles of which enter separately, so as to give to a section across them a sieve-like appearance named *lamina cribrosa*; and the sheaths of the bundles join the sclerotic texture in such a way that the tract of the nerve diminishes in its passage, through the nerve-fibres being collected to a point which is situated one-tenth of an inch internal to the centre of the back of the sclerotic, and slightly below it. In the centre of the optic nerve the central artery of the retina passes in, and the numerous posterior ciliary arteries enter round about the nerve, with two long ciliary arteries—one on each side. The ciliary nerves, about eighteen in number, pierce the sclerotic in a wider circle, and mark its interior surface with grooves for some distance forwards. Adherent to the deep suface of the sclerotic there is a layer of pigmented connective tissue, *membrana fusca*, consisting mainly of flat, pigmented lobate and branched corpuscles with clear nuclei uncovered with pigment. It forms in man a distinct membrane, separated from the choroid coat by one or more lymph-spaces with endothelial lining, which communicate with the interior of the capsule of Tenon by the apertures of emergence of the venae vorticosae. It is also distinct from the sclerotic, and binds down to the sclerotic the ciliary nerves as they course forwards to divide behind the ciliary muscle into branches to supply that muscle and the iris and cornea. Neither ox nor sheep have any separate membrana fusca. In them the sclerotic and choroid are united by densely pigmented connective tissue, which cannot be separated from either.

The cornea. The transparent fore part of the outer coat is slightly thicker at the periphery than in the rest of its extent; and its curvature, which normally is the same in the transverse and vertical directions, is a little more prominent than that of the sclerotic. The plane of continuity with the sclerotic passes obliquely through the thickness of the coat, parallel to the axis of the eye.

The *proper corneal substance* is a modification of white fibrous tissue, arranged in laminae about sixty in number, closely united in the natural

condition, but capable of being swollen by the action of re-agents (*e.g.* weak bichromate of potash), so as to show that the fibres uniting the laminae are less firm than the laminae themselves. The fibres are delicate and straight, those of adjacent laminae decussating; and at the edge of the cornea they are continuous with those of the sclerotic. Nucleated corpuscles are abundant, and in vertical sections appear spindle-shaped,

FIG. 478.—SECTION OF CORNEA, parallel to surface; showing corneal corpuscles lying in branched space. (Beaunis.)

lying between the lamellae; but in horizontal sections are seen to be spread out flat, and to give off slender branches which, when undisturbed, take straight courses, mostly in two decussating lines of direction such as might correspond with the courses of fibres of adjacent laminae, uniting

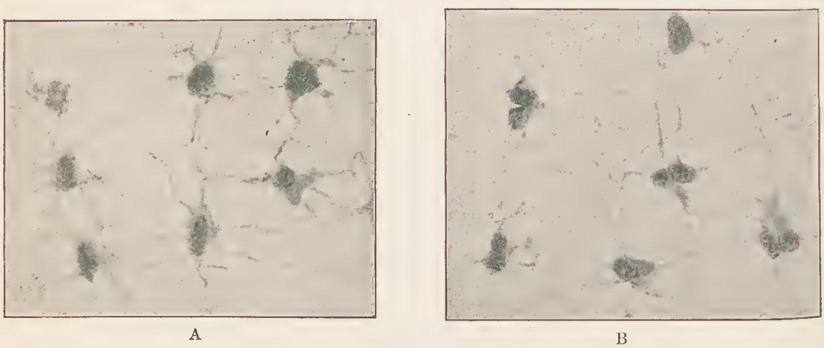


FIG. 479.—CORNEAL CORPUSCLES OF CALF, macerated in vinegar and stained with haematoxylin; photographed. The stained threads of protoplasm are seen in unstained surroundings. In B the corpuscles are multiplying. (Dr. Reid.)

the corpuscles in a network, and also giving off threads parallel to the branches in the other direction. These corpuscles occupy spaces or laminae which intercommunicate, and would appear to correspond pretty closely with them in size and shape, but to be capable of distension. Beaded channels, decussating in like direction with the corpuscular branches, first described by Bowman, have in later years been passed over as artificial structures, but the appearance can be brought into view without injection,

and is a beaded condition of the branches of corpuscles. The laminae nearest the front are more firmly bound together by fibres which extend obliquely inwards from the surface.

In front and behind, the proper substance of the cornea is bounded by elastic substance. The *anterior elastic lamina* (Bowman) is very thin and inseparable, but can be displayed by producing cracks in it by

FIG. 480.—EPITHELIUM OF HUMAN CORNEA. The part to the right is in the neighbourhood of a lesion, which has led to alteration of the tissue and wandering of corpuscles up into the epithelium. (Dr. Reid.)

alternate swelling and shrivelling of the underlying substance. The *posterior elastic lamina* (*membrane of Descemet* or *of Demours*) is much thicker than the anterior and is easily separated; in the horse it can be removed complete. Portions detached curl up, with the anterior surface turned in; it is brittle and structureless. At the circumference it is continuous with the ligamentum pectinatum iridis, which can be removed with it. On its deep surface there is a single layer of squamous epithelium, separating it from the aqueous humour.

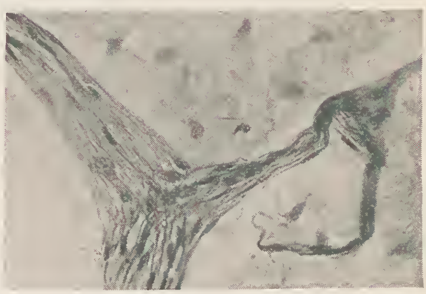


FIG. 481.—PORTION OF PRIMARY NERVE-PLEXUS OF HUMAN CORNEA, highly magnified, showing ganglionic corpuscles and nuclei of nerve-fibres. (Dr. Reid.)

The superficial epithelium of the cornea is in apparently immediate contact with the anterior elastic lamina, and consists in the human subject of elements not very dissimilar from those of the general epidermis. The deepest cells are broad and not greatly elongated, and the strata are not very numerous. But in some animals, as the horse and the ox (Fig. 68), the deepest cells are of a highly elongated columnar form, their pointed extremities striking up between digitations of cells superficial to them; and I was able to make out, superficial to both these strata, a stratum of proliferation (1868).

The nerves of the cornea enter its substance from the sclerotic, near the front. They are branches of the ciliary nerves, over forty in number,

which pierce the sclerotic opposite the ciliary muscle and enter the cornea at a little distance from the surface, to form in it at that depth an open meshwork, the *primary plexus.* From this plexus numerous fine branches pass toward the surface and form a subepithelial plexus on the anterior elastic lamina, whence minute fibres extend to form an intra-epithelial plexus, and end in free and dilated extremities close to the surface. There are no *vessels* in the cornea; the conjunctival capillaries cease after overlapping its border, as already described (p. 645).

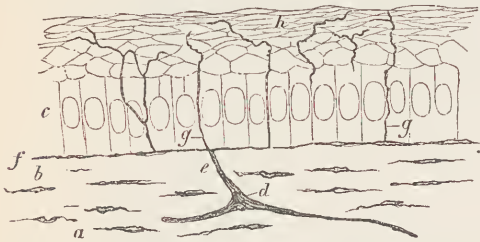


FIG. 482.—CORNEA, EPITHELIUM AND NERVES. *a*, Corneal corpuscles; *b*, anterior elastic lamina; *c*, deep epithelial cells; *d*, primary nerve-plexus; *e*, branch to surface; *f*, subepithelial plexus; *g*, *g*, branches to intra-epithelial plexus, *h*. (Kölliker.)

FIG. 483.—NERVOUS PLEXUS OF CORNEA OF SHEEP under a low magnifying power. The nerves enter the cornea from the periphery at the lower edge of the figure.

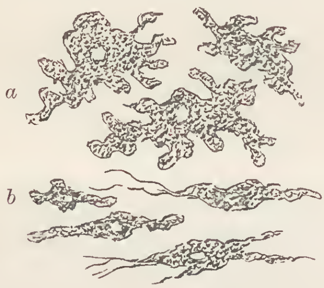


FIG. 484.—PIGMENTED BRANCHED CORPUSCLES. *a*, From membrana fusca; *b*, from between the arteries of the choroid.

The choroid is essentially a vascular membrane, and has the peculiarity that its arteries and veins are spread out in a membranous sheet, and are connected by means of the smallest order of branches with a membranous sheet of capillaries underneath them. The arteries are the short ciliary branches, about twenty in number, of the ophthalmic artery, and, piercing the sclerotic at the back, divide within the membrane; the divisions running directly forwards alongside one of another with narrow intervals between, so that the choroid tears easily in a longitudinal direction. They extend forwards into the ciliary processes, and communicate with the anterior ciliary arteries. The veins, *venae vorticosae*, lie on the sclerotic aspect of the arteries, inseparably united to them, and form a close network ending abruptly in front, opposite the ora serrata of the retina, a little outside the bases of the ciliary processes. They converge to four or five points round the widest part of the globe, and from each of these a

trunk springs, which at once proceeds to pierce the sclerotic backwards. The connective tissue binding the arteries and veins together, the *stroma proper* of the choroid, is made brown by the presence of numerous flat pigmented corpuscles branched like those of the membrana fusca, only to a greater degree. But this stroma is not prolonged on the central or concave surface of the arterial layer. In contact with that surface there is extended the *membrane of Ruysch* or *membrana chorio-capillaris*, a continuous close network of capillaries, with fine meshes, especially at the back of the eyeball, and continued forwards to the ora serrata of the retina,

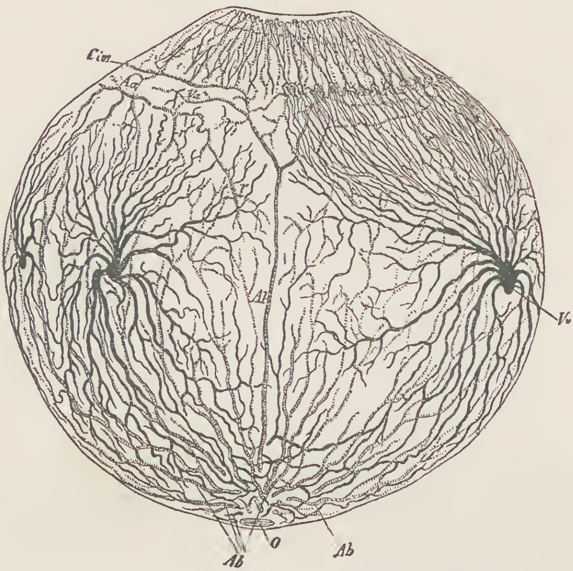


FIG. 485.—SCHEMA OF VESSELS OF THE TUNICA VASCULOSA. On the right side the ciliary muscle is supposed to be removed to bring the ciliary processes into view. *o*, Optic nerve; *Aa* and *Va*, anterior ciliary artery and vein; *Vv*, vena vorticosa; *Al*, long ciliary artery; *Cim*, circulus iridis major; *Ab*, *Ab*, short ciliary arteries. (Leber.)

about an eighth of an inch from the margin of the cornea. It communicates with the arteries and veins by numbers of minute arterioles and venous radicles, not, however, so numerous as in animals provided with a tapetum,[1] such as the ox. In them the capillaries are arranged in a series of stellules, exhibiting in the centre the extremities of short vertical vessels, which traverse the tapetum and give passage to and from the capillaries. The membrane of Ruysch has on its deep or retinal surface a very thin structureless elastic lamina, the *membrane of Bruch*,

[1] The *tapetum* is a structure altogether absent in man, but present in the majority of vertebrates, and most abundant in nocturnal animals and those which require to see below the surface of water. It intervenes between the arterial layer and the membrane of Ruysch, and consists of connective tissue in hoofed animals, of granular matter in carnivora, and of vesicles filled with rods in fishes. In the horse and the ox it is developed in the upper part of the back of the eye so as to catch the images of objects on the ground.

closely but not inseparably adherent to it. The membrane of Bruch rests on the pigmented epithelium described further on.

The ciliary muscle forms a white ring, a tenth of an inch in breadth, extending backwards from the attachment of the iris to the sclerotic. It consists of two sets of unstriped muscular fibres, the radiating and the circular. The radiating fibres arise in the immediate neighbourhood of a groove on the deep aspect of the sclerotic, at the border of the cornea, the *sulcus sclerae.* This groove is the outer border of a lymphatic canal, the circular sinus; and while some of the radiating fibres of the ciliary muscle arise from the iris internal to this canal, others arise from the posterior margin of the sulcus. Diverging from this origin the fibres are inserted on the choroid and into the ring of origin of the ciliary processes. Among the foremost radiating fibres, more or less mixed with them, are the circular fibres first described by Heinrich Müller. The radiating fibres are largely developed in man as compared with the ox and horse, but the circular fibres are not so well developed. In the seals the circular fibres are enormously developed.

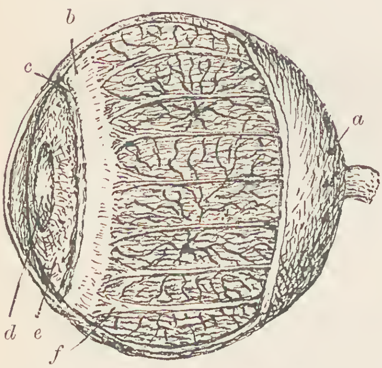


FIG. 486.—HUMAN EYEBALL FROM WHICH PART OF THE CORNEA AND SCLEROTIC HAVE BEEN REMOVED. *a*, Ciliary nerves piercing the sclerotic around the optic nerve; *b*, ciliary muscle; *c*, canal of Schlemm or, more properly, of Fontana; *d*, pupil; *e*, iris; *f*, ciliary nerves dividing toward the front of the choroid in which are seen venae vorticosae and arteries.

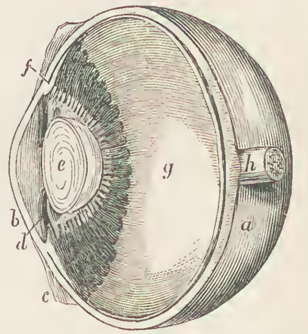


FIG. 487.—SECTION OF HUMAN EYE, $\frac{2}{1}$. *a*, Sclerotic; *b*, cornea; *c*, conjunctiva; *d*, iris; *e*, lens; *f*, ciliary muscle; *g*, retina; *h*, optic nerve. The dentated margin of the white retina is the ora serrata; and between the ora serrata and lens is the ciliary zone, with the most prominent parts of the ciliary processes seen as white rays. Above and below the lens, the canal of Petit exhibits a triangular section.

The ciliary processes are a series of projections forming a circle of rays projecting on the deep side of the tunica vasculosa, separated by an interval called *orbiculus ciliaris* from the ora serrata of the retina and edge of the membrane of Ruysch, their bases being opposite the union of the iris with the ciliary muscle, and each presenting a free extremity which points inwards behind the periphery of the iris. They are erectile structures consisting of a rich vascular network supported by connective tissue continuous with the stroma of the choroid, but without pigment. The arteries of the choroid beyond the edge of the membrane of Ruysch run onwards across the orbiculus ciliaris, dilating as they reach the processes, and are

continued along their free or posterior edges, while the deep parts receive, with the iris, blood from the anterior ciliary arteries. The veins pass back to the choroid, and the capillary network has its vessels enlarged and tortuous.

The iris,[1] the fore part of the tunica vasculosa, is the contractile curtain which gives colour to the eye; it presents in the middle a circular aperture, the *pupil*. But dissectors, supplementing their knowledge by dissection of eyes of other animals, must recollect that the pupil is elongated horizontally in the horse and the ox, while it is elongated vertically in the cat. The iris is connected peripherally with the ciliary muscle and ciliary processes, and, by means of a structure termed *ligamentum pectinatum iridis*, with the membrane of Descemet. It has a stroma of connective tissue presenting

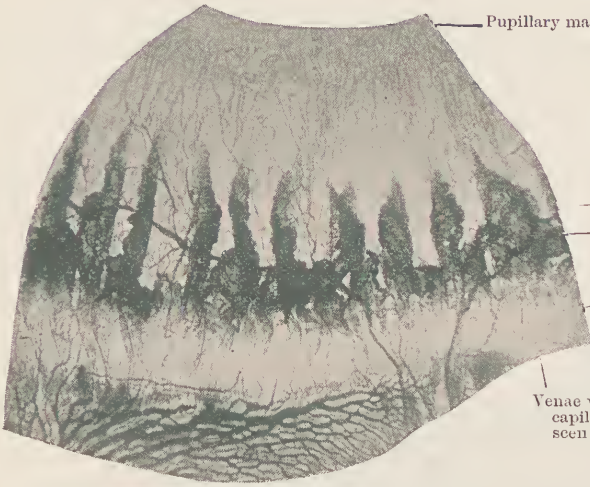


FIG. 488.—INJECTION OF HUMAN IRIS, CILIARY PROCESSES, AND FORE PART OF CHOROID. (Injection by A. Stirling.)

stellate corpuscles with prominent nuclei and long anastomosing branches. Its muscular fibres are unstriped in mammals, striped in birds, and are arranged in two sets. The more distinct set is circularly arranged round the pupil and called the *sphincter*; it is nearer the back than the front. The others, constituting the *dilatator*, are still closer to the back, considerably more scattered and radiate in direction, and stronger peripherally. At the back of the iris there is a continuation of the membrane of Bruch resting on the thick pigmented epithelium behind. In front, at the circumference, the membrane of Descemet, becoming fibrous at the margin of the cornea, turns in to join the fore part of the stroma of the iris, and it is this which is called *ligamentum pectinatum iridis*; but the name is not as descriptive of the appearance in the human subject as it is of the

[1] Uvea of old anatomists, who included under the term the pigmented epithelium behind it. The terms *pars uvealis iridis* for the iris proper and *pars retinalis iridis* for the pigmented epithelium are inaccurate.

arrangement in the ox and in the horse, in which the membrane of Descemet, with tooth-like projections from the iris, is more easily seen to be the sole anterior wall of the sinus circularis. The epithelium lining the back of the membrane of Descemet can be traced round on the front of the iris.

The *arteries of the iris* are derived from the long ciliary and the anterior ciliary arteries. The long ciliary arteries piercing the sclerotic with the posterior ciliaries, pass forwards, one on each side in the choroid, and divide in the periphery of the iris, each into an upper and a lower branch which unite to complete a ring, the *circulus major.* This is joined by branches from the anterior ciliary arteries, five or six vessels which pierce the sclerotic not far from its anterior margin and end also in the supply of the ciliary processes. From the circulus major numerous branches take a convergent course in the depth of the stroma and anastomose so as to form another ring of communication near the pupillary margin, the *circulus minor.*

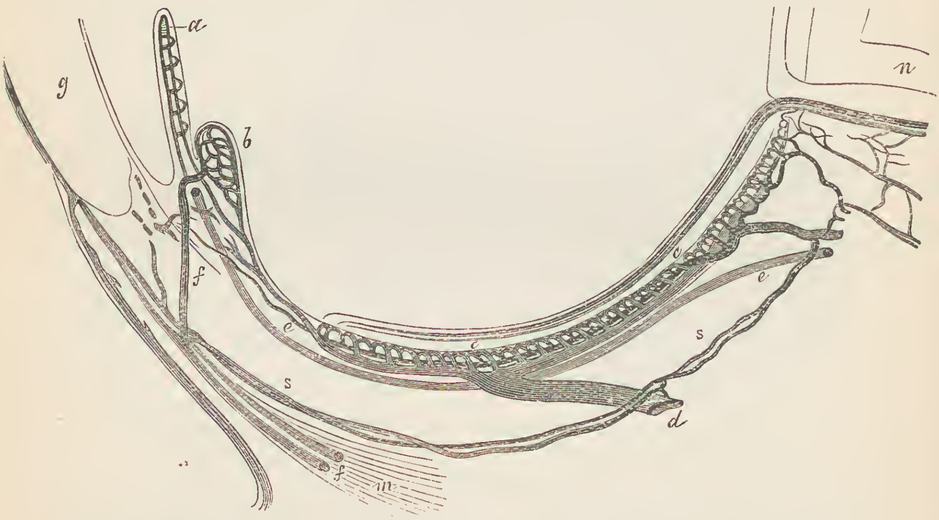


FIG. 489.—SCHEMA OF VESSELS AT DIFFERENT DEPTHS. *a*, Vessels of the iris; *b*, of ciliary processes; *c*, chorio-capillary vessels; *d*, vena vorticosa; *e*, long ciliary artery; *f*, *f*, anterior ciliary vessels and their communication through the sclerotic with the ciliary processes; *g*, the cornea; *m*, one of the recti muscles; *n*, optic nerves and, in it, central artery of retina communicating with others; *s*, episcleral anastomosis. (After Leber.)

The *nerves of the iris* are the terminal branches of the ciliary nerves continued forwards after the giving off of the branches to the ciliary muscle and cornea. These nerves, after piercing the sclerotic, run forwards between the membrana fusca and the choroid, forming a circular series of about fifteen straight trunks which begin to break-up about a tenth of an inch from the ciliary muscle. They enter the iris at the periphery and form a copious plexus in its substance.

Spaces connected with the iris. The space between the cornea and the iris is named the *anterior chamber.* It owes its name to its having been formerly supposed that the iris hung free, with aqueous humour not

only in front but also behind it in a space which was distinguished as the *posterior chamber*; but such an arrangement only occurs as an unusual abnormality detectable by quivering of the iris from want of support. The pigmented epithelium on the posterior surface of the iris rests peripherally on the free tips of the ciliary processes which fit into the plications of the zonule of Zinn, while in its remaining extent it presses on the front of the capsule of the lens. The circular space bounded superficially by the sclerotic groove, and on the deep side by origins of the ciliary muscle and iris, is now generally termed the *canal of Schlemm*, but is undoubtedly the same as the broader canal seen in the ox and other animals, and long known as the *canal of Fontana* or *sinus circularis iridis.* The term *spaces of Fontana* has come into use to indicate a range of intervals between the fibres continued into the iris from the membrane of Descemet, which may be safely described as communicating with other intervals situated between the bundles of the ciliary muscle and giving a netted appearance to radial sections.

The epithelium of the tunica media, named by Max Schultze the *pigmented layer of the retina*, extends to the margin of the pupil. It is developed in connection with the tunica media, and not, as has been erroneously alleged, with the retina; for the retina is the invaginated part of the primary optic vesicle of the embryo, the choroid the uninvaginated part; and the pigmented epithelium, in contact from the first with the choroid, only comes into apposition with the retina at a period later than the appearance of the pigment. In its greater part, behind the ora serrata of the retina, the pigmented epithelium is a single layer, and the cells are hexagonal, each showing a clear nucleus and separated by a clear line from its neighbours. In the perfectly preserved condition they present an outer part or base comparatively free from pigment, and a pigmented deep part prolonged into a multitude of fine thread-like processes dipping between the outer ends of the elements of the bacillary layer of the retina, especially when it has been exposed to bright light. In the choroidal part of its extent the pigment of the epithelium is most abundant at the back of the eye. In the lower animals it is absent from the epithelium over those places where the tapetum is present. In front of the ora serrata—namely, at the back of the orbiculus ciliaris, ciliary processes and iris—the epithelial cells are densely pigmented, close together, of lenticular form, and several layers deep; but the prominent ridges of the ciliary processes are usually left uncovered, and, in a bisected eyeball, shine through the vitreous humour as white rays. In some instances the orbiculus ciliaris is devoid of pigment, while pigment is present both in front of it and behind it.

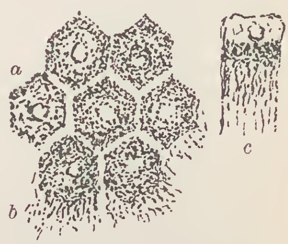


Fig. 490.—Hexagonal Corpuscles of Pigmented Epithelium. *a*, as seen from the surface; *b*, showing the contractile processes; *c*, as seen completely in profile.

Colour of the eye. In those individuals and families occasionally met with, called albinos, there is absence of pigment, not only from the hair, but also from the interior of the eyeball; and the iris is made pink by the colour of the blood circulating within it, while a pinkish light shines through the pupil from the blood in the membrane of Ruysch. In blue and grey eyes the colour is due to the pigmented epithelium forming a dark background to the unpigmented iris proper. The more delicate the tissue of the iris, the purer is the blue colour; and thus, as the iris gets thicker, the blue eye of the child is liable to become grey in after years. Whatever be the exact optical explanation of this, a similar phenomenon is seen in the blue appearance of the sclerotic in many children, lost as the sclerotic becomes more dense. The different shades of hazel and brown eyes depend on the amount of pigment present in the stroma of the iris. This pigment is deposited in branched corpuscles and loose granules, and its special seat is in the fore parts of the stroma.

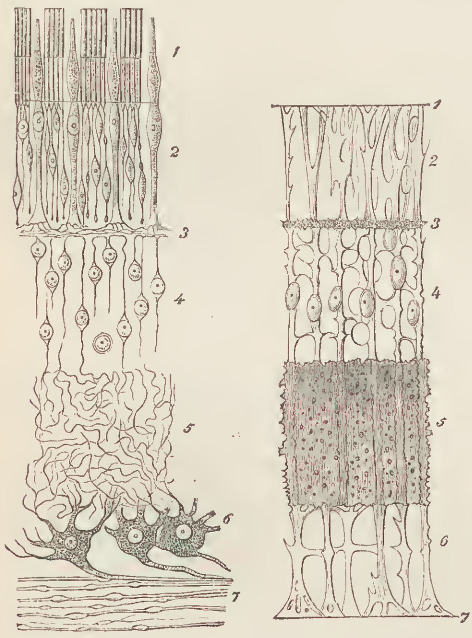


FIG. 491.—SCHEMA OF ELEMENTS OF RETINA. *A*, Special element: 1, bacillary layer, rods and cones; 2, outer nuclear layer; 3, outer molecular layer; 4, inner nuclear layer; 5, inner molecular layer; 6, ganglionic layer; 7, nerve-fibrous layer. *B*, Supportive elements: 1 and 7, external and internal limiting membranes; other numbers as in *A*; the vertical structures between 1 and 7 are Müller's fibres. (After Max Schultze.)

The retina is an exceedingly delicate membrane, but is originally part of the embryonic brain, and remains in its full development a nerve-centre containing both nerve-fibres and nerve-corpuscles. It separates very easily from the coats superficial to it, save only at the *optic pore* or *papilla*, a slightly elevated spot situated one-tenth of an inch internal to the axis of the eye, where the fibres of the optic nerve pierce its outer strata and spread out on the surface turned toward the vitreous humour. It is transparent in the perfectly fresh condition, and of a pale pink colour, except in the central spot, the *macula lutea*, to be separately described. But when eyes are kept in the dark, and removed and examined in sodium or magnesium lights, they exhibit a deep purple colour owing to the presence of a substance called *rhodopsin* in the structures termed the rods. The rhodopsin, or *visual purple*, is rapidly destroyed by exposure to most kinds of light. More gradually the trans-

parent condition gives place after death to a milky white. The retina comes to an apparent margin in front, called *ora serrata*, placed about a tenth of an inch from the ciliary processes, and bounding the orbiculus ciliaris between. The ora serrata is in a continuous line in the ox, but in the human subject it is divided into numerous concavities separated by teeth. Beyond the ora serrata, a cubical unpigmented epithelium, continuous with the bacillary layer described below, lies behind the pigmented epithelium on the ciliary processes, and is called the *ciliary part of the retina.* Dr. Reid has displayed and photographed this layer behind the iris also.

Excluding the pigmented epithelium, seven layers may be distinguished in the retina. The outermost forms in its development the lining of that part of the primary optic vesicle which is not lined by the pigmented epithelium, and it is called the bacillary layer. The other six are included between structureless *external* and *internal limiting membranes,* and consist of an outer nuclear layer, an outer molecular layer, an inner nuclear layer, an inner molecular layer, a ganglionic and a neuro-fibrous layer. These are held together by a considerable amount of delicate substance, constituting a connective framework between the external and internal limiting membranes, and giving, in vertical sections, an appearance of fibres, still known as *Müller's fibres* (Heinrich Müller), broadening out at their attachments to the limiting membranes.

The *bacillary layer,* or *visual epithelium,* consists of vertically placed elements called *rods* and *cones,* both presenting an outer and an inner part: the outer part consisting of a highly refractive but perishable structure stained black by hyperosmic acid and resolvable into thin discs piled one on another; the inner part finely granular, of protoplasmic character, containing at its outer end an elliptical *lens-like body,* also said by some observers to contain a central thread. The inner part was found by Max Schultze to present fine grooves round about, separating apparent fibres which he traced on to the outer part, while, near the base, they were connected with a crown of fine threads coming up from the external limiting membrane. The rods are much the more numerous, and mostly about $\frac{1}{600}$th inch long. Their outer or laminated portion is about half their total length and cylindrical, and their inner or basal portion is much the same shape. Their outer portion is the sole seat of the visual purple. The cones are shorter than the rods, the shortness depending principally on the outer portion, which is also narrower, especially at the apex, and is devoid of visual purple. But the inner or basal portion of the cone is considerably broader than that of the rod. Consequently, looked at from the surface, the ends of the rods are seen lying close together, while the broad bases of the cones appear as larger circles with the tip of the outer portion in their middle. In birds, reptiles and amphibians, the cones present at the outer end of the basal portion oily-looking globules of red and green colour. In amphibians the bacillary structures are of gigantic size.

The mode of action of the rods and cones is to a certain extent deducible from their structure. The discs of the laminated portions are suited for reflecting, from different depths, light striking at all obliquely, and such obliquity will result from passing through any other than the central point of the lens-like body. The rays, when reflected, will return by other courses than those by which they entered, and thus be diffused over different portions of the nerve-endings, whether these be in the centre of the basal elements or lodged in the grooves around. Vertical rays will, in the human eye, be absorbed by the pigmented epithelium behind, as will also such oblique rays as come in contact with the pigmented threads around; but when a tapetum is present there is no pigment to absorb completely penetrating rays, nor to confine rays, either in penetration or reflection, to one rod or cone. No rod or cone can produce more than one sensation or spot of appreciated landscape, and therefore the greater the number in a given area the greater will be the fineness of vision. As all light has to traverse the thickness of the retina to reach the bacillary layer, it is obvious that the nerve-fibres are insensible to the direct action of light; and this is in accordance with the easily demonstrated blindness of the *optic pore*, the spot situated one-tenth of an inch internal to the axis, where the nerve-fibres enter the retina, and where there is necessarily absence of visual epithelium.

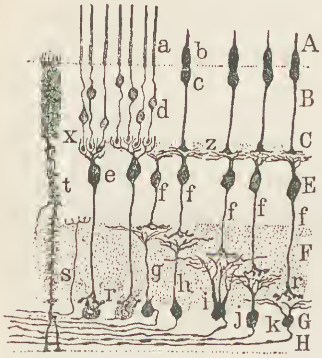


FIG. 492.—DIAGRAM OF CONNECTION BETWEEN BACILLARY ELEMENTS AND GANGLIONIC CORPUSCLES. A, Bacillary layer; B, external granular layer; C, external plexiform; E, internal granular; F, internal plexiform; G, ganglionic; H, optic nerve layer; *a*, rods; *b*, cones; *c*, granule of cone; *d*, granule of rod; *e*, bipolar corpuscle of rods; *f*, *f*, bipolar corpuscles of cones; *g*, *h*, *i*, *j*, *k*, ganglionic corpuscles ramifying in different strata of internal plexiform layer; *r*, *r*, inferior arborizations of bipolar corpuscles; *s*, centrifugal nerve-fibre; *t*, nucleus of Müller's fibre (the latter looked on as epithelial); *x*, terminations of rod-fibres among ascending arborizations of bipolar corpuscles; *z*, contact of arborizations of cones and bipolar corpuscles. (Cajal.)

The external nuclear or *external granular layer* presents at first sight little but a close aggregation of oval bodies. On closer examination these are found to be placed on the course of perpendicular nerve-fibres, each continuous with a rod or cone, those going to the rods being particularly fine and liable to varicosity. The bodies attached to the cones are the larger, they are distinctly nucleated, and, save within the macula lutea, they are pressed up against them, immediately beneath the external limiting membrane. The bodies connected with the rods interrupt the fibres at a variable part of their course; they are oval, and, when fresh, show transverse striation, two or more less refractive lines forming bands in a denser substance. It is noticeable that near the ora serrata this layer diminishes gradually in thickness, while the rods appear to remain as numerous as elsewhere.

The outer molecular or *external plexiform* or *reticular layer* is that in

which the termination of fibres from the external and internal granular layers come into relation. In its superficial part, the rod-fibres are held by Cajal, in opposition to older statements and to Tartuferi and Dogiel, to end each in a spherule, several of which he represents surrounded by the arborization of a single bipolar corpuscle of the internal granular layer. In the deeper part, the cone-fibres give off branches which commingle each with the flattened arborization of a corresponding bipolar corpuscle.

The internal nuclear or *internal granular layer* takes its most obvious character from the bipolar corpuscles just mentioned, whose superficial and deep poles pass respectively into the outer and inner plexiform layers. It contains also *horizontal* or *subreticular cells,* whose ramifications pass out into the external plexiform layer, mingling with the superficial arborizations of the bipolar corpuscles. Cajal divides them into *large* and *small,* both of them with peripheral branches, and with an axis-cylinder ending in an arborization. In like manner at its deeper part this layer presents *spongioblasts* or ramifying cells devoid of axis-cylinders, whose branches descend into the internal plexiform layer.

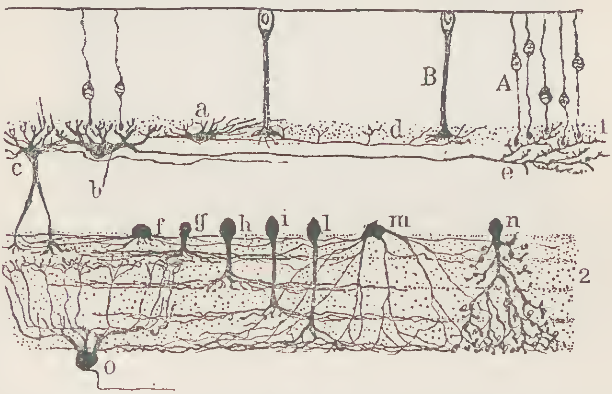


FIG. 493.—CONNECTIONS OF THE HORIZONTAL CELLS AND THE SPONGIOBLASTS OF THE INTERNAL NUCLEAR LAYER. A, B, Prolongations in (1) external nuclear layer from rods and cones; *a*, *b*, small and large horizontal cells; *c*, horizontal cell with descending protoplasmic processes; *d*, *e*, flattened arborizations; *f*, *g*, *h*, *i*, *l*, spongioblasts ramifying at different depths in (2) the internal plexiform layer; *m*, *n*, diffuse spongioblasts; *o*, bistratified ganglionic corpuscles. (Cajal.)

The inner molecular or *internal plexiform layer,* like the external plexiform, is a stratum in which terminal ramifications of different corpuscles come into contiguity. Here the deep terminations from the bipolar corpuscles of the deep granular layer meet at five different levels expansions from ganglionic corpuscles of the following layer, and the spongioblasts also ramify in as many strata.

The ganglionic layer presents large nerve-corpuscles, and is most largely developed at the back of the eye, where the corpuscles lie two or three deep, while in other places they are in one plane and, toward the ora serrata, are scattered. The corpuscles present each an axis-cylinder-pole continuous with a fibre of the neuro-fibrous layer, and usually several

branching superficial poles coming off separately or from a common stem, and directed into the inner molecular layer to end at different depths.

The neuro-fibrous layer lies between the nerve-corpuscles and the internal limiting membrane. The fibres of the optic nerve, before entering the retina, lose their medullary and primitive sheaths, and the naked ampullated axis-cylinders spread out in bundles radiating from the optic pore. Those passing outwards arch so as to avoid the macula lutea, which thus receives its nerve-fibres from its whole periphery.

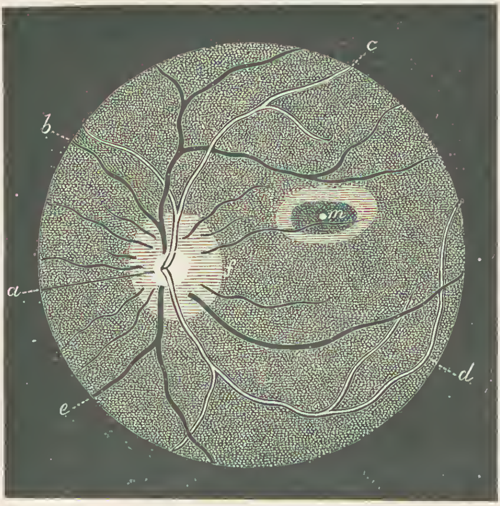


FIG. 494.—OPHTHALMOSCOPIC VIEW OF CENTRE OF RETINA. *a*, Optic papilla; *b*, *e*, veins; *c*, *d*, arteries; *f*, limit of apparent area of papilla; *m*, fovea centralis. (Beaunis after Galezowski.)

The central artery of the retina, entering it in the centre of the fibres of the optic nerve, divides at once into branches, usually an upper and a lower, which, avoiding the macula lutea, spread out in the neuro-fibrous layer, and together with the nearly corresponding veins can be seen for some distance during life by means of the ophthalmoscope. They are alleged to be surrounded by perivascular lymphatic spaces (His). The capillaries reach no further outwards than the external molecular layer, the external nuclear being non-vascular.

The macula lutea, or yellow spot of Soemmering, is situated in the axis of the eye, and is a transversely oval depression about $\frac{1}{12}$th inch in diameter, rendered yellow by a diffuse staining in the vascular layers. In the centre there is an appearance of a perforation, *fovea centralis*, caused by the absence of those layers. In the macula lutea the cones are greatly increased in number, and in the fovea centralis they replace the rods altogether, at the same time that they attain the elongation of rods and become greatly narrower than elsewhere. The optic nerve-fibres, as already explained, consist only of those required for the macula itself, and even they are absent from the fovea centralis, as the nerve-fibres of the nuclear

layers slope obliquely to that spot. The ganglionic layer in the macula lutea has its corpuscles greatly increased in number, lying five or six deep, and with the protoplasmic poles reduced to one each; but in the fovea centralis the nerve-corpuscles are altogether absent. Also the inner nuclear layer is absent in the fovea centralis, and the outer nuclear layer shows one corpuscle for each cone, separated by a certain distance from the external limiting membrane.

The fovea centralis receives images from an area of about quarter of an inch at ten inches from the eye, and it is easy to observe by fixing the eye on one letter in a line of print at that distance that this is the full extent of the most distinct vision. The accumulation of cones in the fovea centralis appears, therefore, to prove that they are more perfect structures than rods, while their smaller size here than elsewhere gives a greater number of separately recognizable points within a limited space.[1]

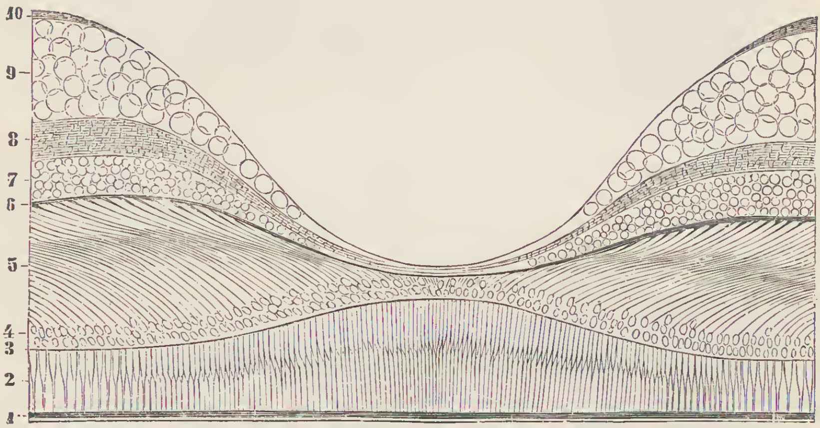


Fig. 495.—Schema of Section through Fovea Centralis and Macula Lutea. 1, Pigmented epithelium; 2, cones; 3, external limiting membrane; 4, external nuclear layer; 5, fibres of cones; 6, external plexiform layer; 7, internal nuclear layer; 8, internal plexiform layer; 9, ganglionic layer; 10, nerve-fibrous layer and internal limiting membrane. (After Max Schultze.)

The transparent structures within the eyeball consist of the vitreous body, the crystalline lens and membranes which surround them so that they can be removed from the globe in one coherent mass.

The vitreous body or *vitreous humour* fills up, together with the crystalline lens, the space surrounded by the three coats of the eye. It is a transparent substance, bright and colourless, which, when unsupported, alters its shape like a delicate jelly. It is surrounded by a closely adherent transparent and structureless *hyaloid membrane*, more tenacious than its internal substance; and this is inseparably united in front with the capsule investing

[1] Obviously there is no separate communication between the brain and each rod or cone, and the brain cannot receive separate impressions from each. See Cleland, "Physical Relations of Consciousness," *Journal of Anatomy and Physiology*, November, 1870. Recent researches make the truth then put forward more abundantly evident.

the lens, so that when the coats of the eye are removed three transparent structures remain in one connected mass. The posterior wall of this capsule is sunk in the vitreous humour so as to hollow it in front into a *fossa patellaris*. The vitreous body consists of solid and fluid constituents which can be distinguished by draining. It can be made opaque by hardening reagents, and can be kept nearly transparent in spirit by careful previous treatment with weak bichromate of potash. When hardened it tends, towards the *circumference*, to tear in concentric laminae, and it also tears easily in directions radiating from the axis of the eye. But only two definite structures have been found in it, namely, first, sparsely scattered amoeboid corpuscles with distinct clear nuclei, and the *canal of Cloquet* (verified by Stilling and Schwalbe), a straight channel about $\frac{1}{25}$th inch in breadth, extending from the optic pore to the back of the capsule of the lens, in the position of an ante-natal artery and communicating with the lymphatics of the optic nerve.

FIG. 496.—FOUR ELONGATED CONES FROM CENTRAL SPOT. *a*, Pile of refractive discs; *b*, basal parts of cone; *c*, external limiting membrane; *d*, corpuscle situated in the course of the fibre from the cone. (Schultze.)

The crystalline lens is a firm transparent structure, with a circular outline placed on edge, about one-third of an inch in diameter; and with an anterior and a posterior convex surface, the posterior the more prominent, and an axial thickness from before backwards of about a fifth of an inch. Neither surface is spherical; but in both the curve increases as it approaches the circumference. The lens is closely surrounded by a capsule, and on removal from this, soon begins to exhibit a concentrically laminated structure, each lamina breaking up into segments. The lines of fracture extend from the centres of the two surfaces, three on each. Those in front are directed, one upwards and the others at equal angles from it and from one another; while of those behind, one extends downwards, and the others diverge in upward directions in the intervals between those in front. When by the weight of the lens resting on it one surface is kept from breaking up, the other breaks into six. The outer laminae are less firm than those which they surround, and the density increases gradually till the central part is reached, which is very firm and called the nucleus. Both laminae and nucleus consist of altogether peculiar fibres directed from before backwards, and each presenting in the young condition a nucleus

FIG. 497.—LENS BREAKING UP. *A*, Three lines extending from the central point in front, and the extremities of three alternating lines from the central point behind; *B*, six segments separating in front and exposing the nucleus, in the case of a lens exposed on a flat surface.

in front of the equator of the lens, which, however, in the adult lens has disappeared, except in the most superficial fibres. The fibres, broad in the middle, are attenuated in part of their extent. They are bound together by a cement which is specially abundant and granular in the lines where the laminae break up (though, indeed, this has been denied). Those in the heart present hexagons in tranverse sections, while those at the circumference are flattened. But the most characteristic feature is that the edges present each a single row of what are usually described as serrations, which are in reality (as I find both in the horse

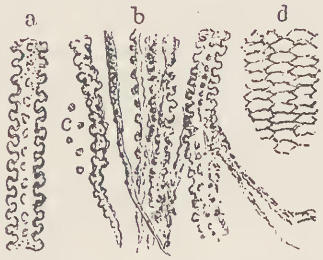


FIG. 498.—LENS-FIBRES. *a*, Portion of fibre from lens of horse, completely isolated, and showing three of the rows of knobs; *b*, portions of fibres of lens of horse less completely isolated; *c*, separated knobs as seen both in horse and in human subject; *d*, transverse section of fibres of human lens.

FIG. 499.—HUMAN LENS AND SUSPENSORY APPARATUS, $\frac{4}{1}$. From preparation displayed in spirit. *a*, Canal of Petit; *b*, canal opened into; *c*, suspensory fibres of its anterior wall; *d*, plicated hyaloid membrane with adherent pigmentary corpuscles.

FIG. 500.—PORTION OF SUSPENSORY LIGAMENT AND CANAL OF PETIT OF OX, $\frac{4}{1}$, from specimen displayed in spirit. *ab*, Smooth hyaloid membrane; *bc*, attachment of zonular fibres; *cd*, plications of hyaloid membrane with secondary plications to fit into secondary recesses between ridges of ciliary processes; *de*, suspensory ligament with crowded hollow processes; *ef*, hair-like passages injected from canal of Petit; *g*, anterior wall of capsule; *h*, posterior wall of capsule; *i*, section of canal of Petit.

and the human subject) pedunculated knobs, the peduncles being often the only parts seen on account of the extremities being broken off and lying about. The uncompressed fibres have six rows of knobs. Steeping in muriatic acid is good for their display. The fibres rest behind in contact with the capsule; and in this situation fluid, "*liquor Morgagni*," is liable to collect in drops after death. In front a single layer of squamous epithelium intervenes between the lens and the capsule; and at the circumference of the lens the cells of this epithelium are in series with short fibres, the latest additions to the structure of the lens itself.

The capsule of the lens closely surrounds it and presents an anterior and

a posterior wall, which, though both of them structureless, differ considerably in consistence. The anterior wall is thicker than the posterior and elastic to such an extent that when ruptured it causes, by its pressure, the lens to escape, while the ruptured edges turn inwards. The posterior wall when separated from the vitreous humour and ruptured does not curl inwards, being less distinctly elastic. It has the hyaloid membrane closely united with it.

Suspensory apparatus and zonule of Zinn. When the vitreous body and the lens are removed together from the parts which inclose them, a circle of radiating plications is seen beyond the circumference of the lens, and to this circle it is usual to give the name zonule of Zinn. The plications fit in closely between and behind the ciliary processes, and there adheres to them a greater or smaller amount of the intervening pigmented epithelium. From the prominent margin of the fossa patellaris a structure exhibiting

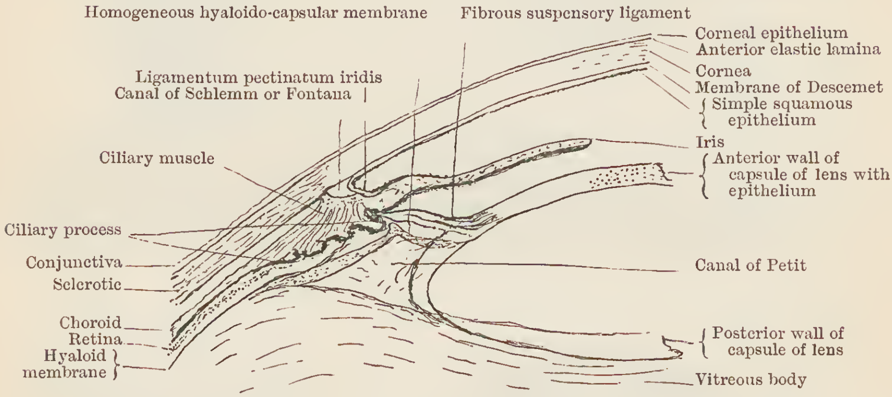


FIG. 501.—SECTION THROUGH CAPSULE OF LENS, SUSPENSORY LIGAMENT AND CANAL OF PETIT.

radiating fibres extends inwards to the circumference of the anterior wall of the capsule of the lens, and this is what is properly termed the *suspensory ligament* of the lens. If it be punctured, coloured injection can with the slightest pressure be made to fill a three-sided space behind it, which is limited centrally by the peripheral part of the posterior wall of the capsule of the lens, and posteriorly by the hyaloid membrane. This is the *canal of Petit.* This canal has not been alleged to have an endothelial lining; and, in point of fact, it is traversed by a certain amount of tissue allowed to be so delicate as to be easily destroyed in removal of the ciliary processes from the plications of the zonule. This delicate tissue is the so-called *prismatic ligament*, and has even been figured under the name of ligamentum suspensorium lentis, but is not comparable in tenacity with any of the three walls of the canal of Petit.

The *suspensory ligament* proper, the anterior wall of the canal of Petit, has a much more complex structure than it has been credited with. Thick sections of the human eye, made by the writer, show distinctly

under the microscope a homogeneous *hyaloido-capsular membrane* behind the recognised *suspensory* or *zonular fibres.* But neither the suspensory ligament nor the canal of Petit can be completely studied by means of sections, especially very thin sections. If perfectly fresh eyes are treated with exceedingly weak bichromate of potash, to which spirit is afterwards added, the pigmented corpuscles and those of the ciliary part of the retina have their cement dissolved and allow the transparent structures, including the middle part of the zonular fibres, to separate easily from the recesses peripheral to the iris. It is then seen that the zonular fibres take rise from the hyaloid membrane beyond the fossa patellaris, and are inserted into the front of the capsule of the lens by flattened attachments. Successful injections display converging straight thread-like passages extending from the canal of Petit a little way on the front of the capsule. The part of the suspensory ligament fastened in the fresh state to the recesses round the iris exhibits hollow prominences; and these have unpigmented corpuscles adherent to them which are probably the structures described as *ciliary glands.*

Development of the Eye.

The eye is developed partly from the brain and partly from the surface of the embyo; the retina and choroid being in fact portions of the brain and pia mater, while the lens is of cuticular origin, and the sclerotic, cornea, iris and vitreous body are derived from intervening mesoblast.

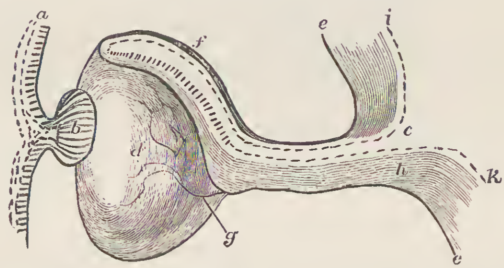


Fig. 502.—Diagram of Development of Eye. *a*, Conjunctival epithelium; *b*, lens-fibres continuous with deepest epithelial layer; *c*, neck of primary optic vesicle; *d*, secondary optic vesicle; *e*, *e*, pia mater; *f*, *g*, choroid coat and the retinal artery both continued from the pia mater; *h*, nervous substance continued into retina; *i*, epithelium of ventricle continuous with pigmented epithelium; *k*, epithelium of ventricle continuous with bacillary layer.

The cerebral part of the eye is the earliest to appear, and begins in the chick at the end of the first day of hatching, in connection with the first cerebral vesicle, as a rounded lateral portion, the *primary optic vesicle*, nearly as large as the mesial portion or first vesicle proper, and separated from it by a partition which rises up from the ventral aspect and reaches back to the middle line at the constriction between the first and second cerebral vesicles, where it meets its fellows to form the anterior edge of the future optic commissure. Thus the vesicle becomes pedunculated, and

the peduncle is the future optic nerve. Soon the primary optic vesicle and fore part of its peduncle become folded in, the lower and fore part of the vesicle being invaginated so as to come in contact with the upper and back part, and the edge of invagination becomes divided into a circular fore part and two retreating lower edges, which approach one to the other, so as to complete a cup, the *secondary optic vesicle.* At the same time that the primary optic vesicle is invaginated to form the cup of the secondary vesicle, a superficial depression appears opposite the mouth of the

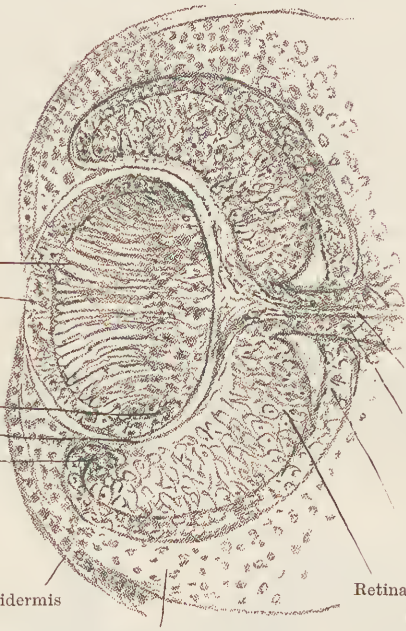


FIG. 503.—SECTION OF EYE OF EMBRYO RAT. The place of continuity of the retina and choroid at the invagination of the primary optic vesicle is seen. (Preparation by Dr. Mackay.)

cup, and deepens to a pit which becomes constricted at the neck and closed off as a shut sac embedded in mesenchyma and lined with epithelium, to be converted into the lens; while from the mesenchyma are derived the vitreous humour, iris and outer coat of the eyeball. The pigmented epithelium appears in the chick toward the fourth day, and it then becomes evident that the non-invaginated portion of the wall of the primary optic vesicle is converted into choroid and pigmented epithelium, while the invaginated part is converted into retina. There is no development of brain-matter from the non-invaginated wall, and therefore the vessels and epithelium come in contact exactly as they do at the choroid plexuses of the brain; while the retina, being formed from the invaginated wall, has its originally superficial surface turned to the centre of the eyeball, has its vascular supply on that surface, and has the surface originally looking

into the brain-cavity applied to the pigmented epithelium. The bacillary layer is late in developing, and is thought to proceed from the outer nuclear layer, which perfectly accords with the view that each rod or cone is part of the same corpuscle as the structure connected with it below the external limiting membrane.

The lens becomes solid by the elongation of the cells lining the hinder half of its capsule, till they press against those of the anterior half, which remain permanently as epithelium. For a considerable time it occupies a large part of the cavity of the eye, is nearly spherical, and in close contact with the cornea which has intruded between it and the superficial epithelium. At the same time the retina is proportionally thick and the vitreous body small in amount. The fibres in the centre are long, and the new fibres are added at the circumference; and in antero-posterior sections the nuclei of the fibres form a broad belt with a convexity forwards, which is at first near the back, but afterwards toward the front. The capsule of the lens receives an artery, the *hyaloid branch* of the central artery of the retina, which extends from the optic pore to the middle of the posterior surface, and is connected with the tunica vasculosa at the circumference, whence vessels converge in front. In later development the whole eye expands, increasing the cavity behind the lens and forming the anterior chamber in front, while the connection between capsule of lens and tunica vasculosa stretches out as the iris. In the centre of the iris, the fore part of the vascular capsule of the lens, being continuous with it, occludes the future pupil, and is often called *membrana pupillaris.* These vascular arrangements disappear in the human foetus before birth, but in some animals—as in the kitten—persist for a short time after.

The eyelids make their first appearance in the third month of foetal life. They afterwards become united together by cohesion of the epithelium on their edges, which continues till shortly before birth. The lachrymal ducts correspond in position with the lines of junction of the maxillary lobes and lateral nasal processes. They are originally superficial, and become deeper by the growth forwards of surrounding parts.

THE EAR.

The ear consists of three parts, called the external, middle and internal ear; the external and middle ear being separated one from the other by the *membrana tympani* and both of them filled with air, while the internal ear, which contains the whole distribution of the auditory nerve, is filled with fluid.

The External Ear.

The external ear consists of the expanded part or *pinna,* and the tube leading down to the membrana tympani, the *external auditory meatus.* The cup of the pinna is called the *concha,* the pendent part is the *lobule,*

and the incurved prominent margin starting in front of the concha and carried round from above to end behind at the base of the lobule is the *helix*. Between the back of the concha and the helix there is a prominence called the *antihelix*, formed by folding of the supporting cartilage and bifurcated above. The depression between helix and antihelix is called the *fossa of the helix*, and that lying in the bifurcation of the antihelix is the *fossa of the antihelix*. In front of the meatus a prominence, often hairy, called *tragus*, projects backwards, while, behind it, another prominence, the *antitragus*, points forwards and upwards. The lobule consists of adipose tissue, in a firm stroma of white fibres, and is liable to considerable variation in form and size. The rest of the pinna is supported by cartilage.

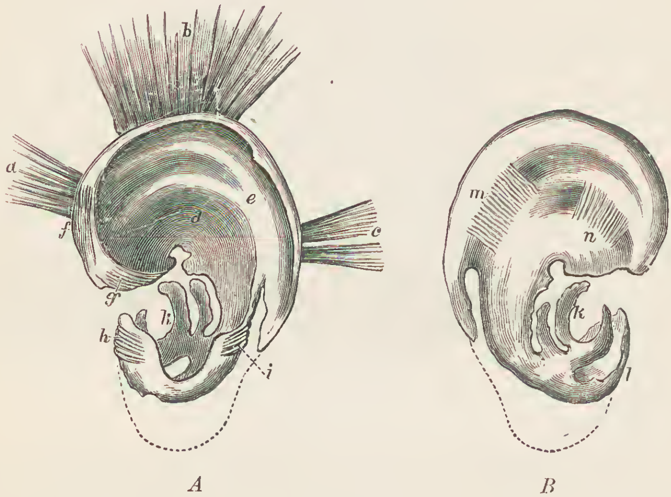


FIG. 504.—CARTILAGE AND MUSCLES OF EXTERNAL EAR. *A*, Outer aspect; *B*, cranial aspect; *a*, *b*, *c*, attrahens, attollens and retrahens auriculam muscles; *d*, concha; *e*, antihelix; *f*, *g*, large and small muscle of helix; *h*, tragus and tragic muscle; *i*, antitragus and antitragic muscle; *k*, the edge of the cartilage which is attached by fibrous tissue to the external auditory meatus of the temporal bone; *l*, tragus from behind; *m*, transverse muscle crossing the sulcus at the back of the antihelix; *n*, oblique muscle crossing sulcus at the back of the inferior branch of the antihelix. The lobule is represented in dotted outline.

The *cartilage* of the pinna presents in its texture an abundance of hyaline matrix threaded with networks of fibres mostly of yellow elastic character. It not only enters into the construction of the pinna, but also bounds the part of the meatus superficial to the external auditory process of the temporal bone, to which it is attached by fibrous tissue. It is a continuous sheet folded round the meatus, with one border at the anterior end of the helix, and the other looking upwards above the tragus, which is a projection of the free margin, as is also the antitragus. The cartilage presents in its unexpanded part two or three gaps, *fissures of Santorini*, placed transversely to the direction of the meatus. On the upper and back part of the edge of the helix there is often a small point or tubercle (Fig. 504, A) to which Darwin attracted attention, adopting the view sug-

gested by Woolner the sculptor that it represented the tip of the ear in the lower animals. The inferior extremity of the cartilage of the helix is separated by a deep cleft from the upper edge of the antitragus. An *anterior ligament* extends from a tubercle on the front of the helix to the root of the zygoma; and a *posterior ligament* passes from a thickening at the back of the concha to the mastoid process; while the *attrahens, retrahens* and *attollens auriculam* muscles likewise attach the cartilage to the skull (p. 330). More minute collections of muscular fibres pass from one part of the cartilage to another, but are not constantly developed. They are: (1) the *greater muscle of the helix*, on the anterior convexity; (2) the *smaller muscle of the helix*, below the greater, and attaching the helix to the concha; (3 and 4) the *tragic* and *antitragic*, on the outer sides of the tragus and antitragus; (5) the *transverse muscle*, consisting of fibres bridging the concavity of the fold forming the antihelix; and (6) the *oblique*, a smaller set of fibres bridging the concavity of the inferior division of the antihelix.

The *external auditory meatus* or *canal* extends from the concha to the membrana tympani. It is walled in by the cartilage of the pinna in its superficial part and by the temporal bone more deeply. Its entrance as it leaves the concha under cover of the tragus has a forward inclination; and immediately internal to the concha it turns transversely inwards, but immediately resumes a forward inclination, which it preserves in the rest of its extent. It is also sloped somewhat upwards from its commencement till within the bony canal, where it inclines downwards. Thus, the whole passage is straightened by pulling the pinna upwards and backwards; and when a speculum is introduced a certain distance, its outer end has to be raised to bring the membrana tympani into view. The integument lining the meatus becomes thinner and more sensitive in the osseous part. The cartilaginous part has few and ill-marked papillae. It is furnished with hairs which have an outward slope and are provided with sebaceous glands. But much more remarkable are the *ceruminous glands* which secrete the wax; they are of similar structure to the sudoriparous glands elsewhere, but much larger. In the deep parts the hairs and glands disappear, and papillae are well marked and numerous.

Arteries and nerves. The external ear receives branches from the posterior auricular, superficial temporal and internal maxillary arteries, and is supplied with nerves by the posterior auricular branch of the facial, the auriculo-temporal branch of the third division of the fifth, and the great auricular and small occipital nerves from the cervical plexus.

The Middle Ear.

The middle ear, the *tympanum*, presents principally for consideration the tympanic cavity, the ossicles with their muscles, and a mucous membrane; and connected with it are the membrana tympani and the Eustachian

tube. The tympanic cavity is a space measuring approximately one-eighth of an inch from without inwards, half an inch from above downwards, and three quarters of an inch in its longest diameter, which extends forwards and inwards. It is bounded internally by the pars petrosa of the temporal, is roofed mostly by the lamina of the pars petrosa called *tegmen tympani*, and is floored by the tympanic plate. It communicates behind with the mastoid cells; and into the formation of its outer wall there enter the membrana tympani, the pars squamosa and the tympanic plate; while, in front, it narrows to the Eustachian orifice. The walls exhibit various points of interest. On the margin of the deep end of the external auditory meatus there is a distinct sharp-edged groove, absent only from the part above and in front, where there is a notch, the *notch of Rivini*, and the meatus is completed by the pars squamosa. In the inner tympanic wall there are two foramina. One of them, *fenestra ovalis*, is elongated transversely and is occluded in the recent state by the base of the stapes; the other,

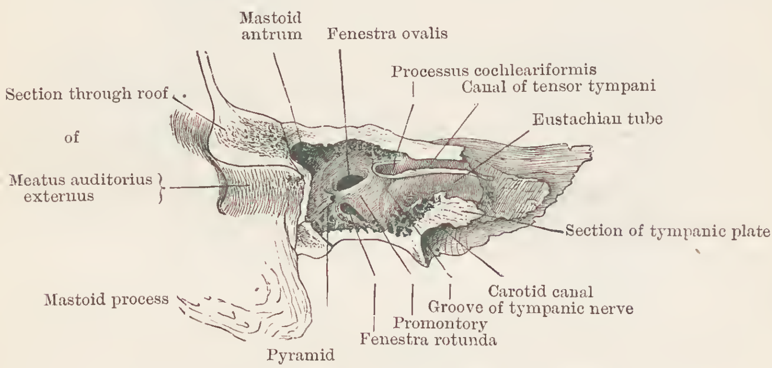


FIG. 505.—INTERNAL WALL OF TYMPANIC CAVITY. (Pansch.)

fenestra rotunda, placed below the fenestra ovalis and looking backwards and outwards, is occluded by membrane, the *secondary membrane of the tympanum.* Above and in front of the fenestra rotunda there is a convexity, the *promontory*, corresponding with the commencement of the cochlea. Above the fenestra ovalis the wall of the aqueduct of Fallopius projects as it passes backwards, after having crossed transversely outwards above and between the cochlea and vestibule. In the posterior wall of the tympanum the same tube turns outwards before descending to the stylomastoid foramen by a course in which it is no longer seen from the tympanic cavity of the dry bone. Above the aqueduct of Fallopius a large irregular recess, the *mastoid antrum*, leads back into the mastoid cells. This antrum exists before birth, though the mastoid process beneath it only becomes gradually swollen out in future years by cells lined with mucous membrane prolonged from the tympanum. On a level with the fenestra ovalis the posterior wall presents an elevation, *the pyramid*, with a perforation in its summit for the passage of the tendon of the stapedius

muscle; and when the bone at this part is laid open, the perforation is seen to lead into a more dilated space for the stapedius muscle, passing down in front of the aqueduct of Fallopius and communicating with it below. Immediately in front of this, in the young subject the root of the styloid process may be made out sheathed by a lamina derived from the pars petrosa, and superficial to the pyramid is a foramen leading from the aqueduct of Fallopius and giving passage to the chorda tympani nerve.

The ossicles of the ear, three in number—the malleus, the incus and the stapes—are joined together so as to connect the membrana tympani with the fenestra ovalis; and by swinging movements round a line joining two fixed points, one in front and the other behind, they regulate pressure on the internal ear, in harmony with the tension of the membrane.

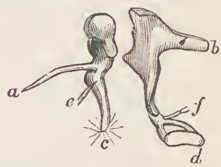


FIG. 506.—TYMPANIC OSSICLES OF RIGHT EAR. *a*, Processus gracilis of malleus; *b*, posterior process of incus; the line *ab* is the axis of rotation. When *c*, the handle of the malleus, with fibres of the membrana tympani radiating from its extremity, is pulled inwards by *e*, the tendon of the tensor tympani, the incus likewise rotates and pushes *d*, the stapes, in at the fenestra ovalis; *f*, tendon of stapedius.

The *malleus* presents at its upper end a thick rounded head with an obliquely saddle shaped surface behind for synovial articulation with the incus, and is connected with the roof by a fold of mucous membrane which may contain fibres (*ligamentum mallei superius*). The head is supported on a neck (or body) connected by an *external ligament* to the outer wall above the membrana tympani; and from the front of the neck a long *processus gracilis* extends forwards to end in a thin flattened extremity embedded in fibrous tissue (*ligamentum anterius*) in the fissure of Glaser. Immediately below the processus gracilis, the malleus is thickened by a sudden projection outwards, the *processus brevis*, whose summit is the uppermost point of attachment to the membrana tympani; and thence it descends as a stout prolongation, the *manubrium* or *handle*, compressed from before backwards and ending in a knob which furnishes a centre of radiation for fibres of the membrana tympani.

The *incus*, placed behind the malleus, presents on the front of its thickest part or *body* a saddle-shaped surface fitting to that of the malleus. It sends out two processes. One, the *posterior process*, is conical, and passes backwards to be attached at its extremity by ligamentous union in front of the descending part of the aqueduct of Fallopius. The other, the descending process, longer and cylindrical, is turned inwards abruptly at its extremity to end in an orbicular articular surface. This is the *os orbiculare* of some older anatomists, and articulates synovially with the head of the stapes.

The *stapes* lies horizontally between the fenestra ovalis and the orbicular extremity of the descending process of the incus. Its base is a plate fitting against the vestibular aspect of the margin of the fenestra ovalis, united to it by membrane or annular ligament, so that when the stapes is pushed by the incus the ligament is tightened and the contents of the

internal ear pressed upon. The lower edge of the base is distinguished from the upper by a slight concavity. Two arched crura spring from the base, the hindermost somewhat more curved than the other, and then join to form a short neck supporting a disc-like head which articulates synovially with the incus.

There are two distinct muscles in connection with the ossicles. The more important is the *tensor tympani.* It has a muscular belly fully half an inch long, lying beneath the adjacent margins of the sphenoid and pars petrosa, and resting on the cartilaginous part of the Eustachian tube, from which it principally arises. Its tendon enters the tympanum above the cochleariform process, and is held by that shelf of bone until opposite

FIG. 507.—DIAGRAM OF THE RIGHT EAR. *a*, Osseous part of the canal of the external ear; *b*, membrana tympani with the upper part removed; *c*, malleus; *d*, incus; *e*, stapes with its base filling up the fenestra ovalis (the fenestra rotunda is seen a little lower); *f*, Eustachian tube; *g*, tensor tympani muscle; *h*, stapedius muscle; *i*, *i*, the facial nerve divided; *k*, mastoid cells; *l*, *m*, vestibular and cochlear divisions of the auditory nerve; *n*, vestibule; *o*, cochlea.

the malleus, when it turns abruptly outwards over the end of the bony shelf, and crosses the tympanic cavity to be inserted into the handle of the malleus near its root. It thus pulls the handle inwards, and makes tense the membrana tympani; but it ought to be noticed that its insertion so high up on the handle, while it diminishes its leverage to rotate, gives it an inward pull on the whole bar round which rotation takes place, extending from the tip of the posterior process of the incus to that of the processus gracilis. The other muscle, the *stapedius*, lies in the space already indicated within the pars mastoidea, and, passing upwards, ends in a tendon, which emerges at the foramen of the pyramid and passes forwards to be inserted into the neck of the stapes. It is calculated, by contracting when the action of the tensor tympani is extreme, to relieve pressure on

the internal ear by producing an oblique position in which only the posterior fibres of the annular ligament will be tightened, while anteriorly the base of the stapes is pressed against the vestibular side of the wall of the fenestra.

The mucous membrane of the tympanum is prolonged from the pharynx through the Eustachian tube, and extends back to line the mastoid cells. Its folds are not quite constant in their arrangement. It surrounds cylindrically the stapes and lower end of the descending process of the incus. Above the incus it is prolonged from behind on the outer wall of the tympanum to the malleus, forming the boundary of a *posterior fossa.* It also connects the posterior or short process of the incus, together with the chorda tympani nerve, to the outer wall. In front of the head of the malleus the chorda tympani and processus gracilis of the malleus are connected by a fold to the outer wall; and above this is the *anterior fossa*, separated from the posterior by the superior and external ligaments of the malleus. A small recess between the external ligament and the short process of the malleus is called *Russac's space*, and lies opposite the portion of the membrana tympani in the notch of Rivini. In structure the mucous membrane is very thin, and for the most part it is closely connected with the periosteum. It is lined with columnar ciliated epithelium on the floor and internal wall; but this is changed for a single layer of squamous cells on the tympanic membrane. The mucous membrane of the middle ear is supplied by Jacobson's nerve, the tympanic branch of the glosso-pharyngeal.

FIG. 508.—RIGHT MEMBRANA TYMPANI. $\frac{2}{1}$. *A*, From outside. *B*, From within, with malleus and incus in situ.

The *membrana tympani* separates the middle from the external ear. It is attached to the inner extremity of the meatus auditorius externus, and lies obliquely to it, its inferior edge being nearer the mesial plane than the superior, and the anterior nearer than the posterior; so that the lower and anterior part forms an acute angle with the floor of the meatus, and the upper and posterior part an obtuse angle with its roof. Below the middle, it presents an *umbo* or apex of a shallow cone, directed inwards, corresponding in position with the tip of the handle of the malleus, and sometimes in the living subject permitting indications of the form of that structure to be seen. Above, in the notch of Rivini, there is a little

depressed and slack portion, the *membrana flaccida* of Shrapnell. The membrana tympani consists of three layers—namely, the proper fibrous membrane, an outer covering from the integument, and an inner covering of mucous membrane. The fibrous layer consists principally of fibres radiating from the tip of the handle of the malleus; but toward the circumference these have been found to be crossed on their tympanic side by thin annular fibres. Attention does not seem to have been directed to the fact that the circular groove of the tympanic plate is mainly occupied by a strong ring of fibres, and that it is this ring which is continued across the notch of Rivini and separates the membrana flaccida from the rest of the membrane. The tegumentary covering is thin and destitute of papillae. The handle of the malleus, from the processus brevis to near the tip, is between the mucous layer and the fibrous, its periosteum being closely united to the latter; and close to the sides of this line of union there is greater vascularity of the mucous membrane than elsewhere.

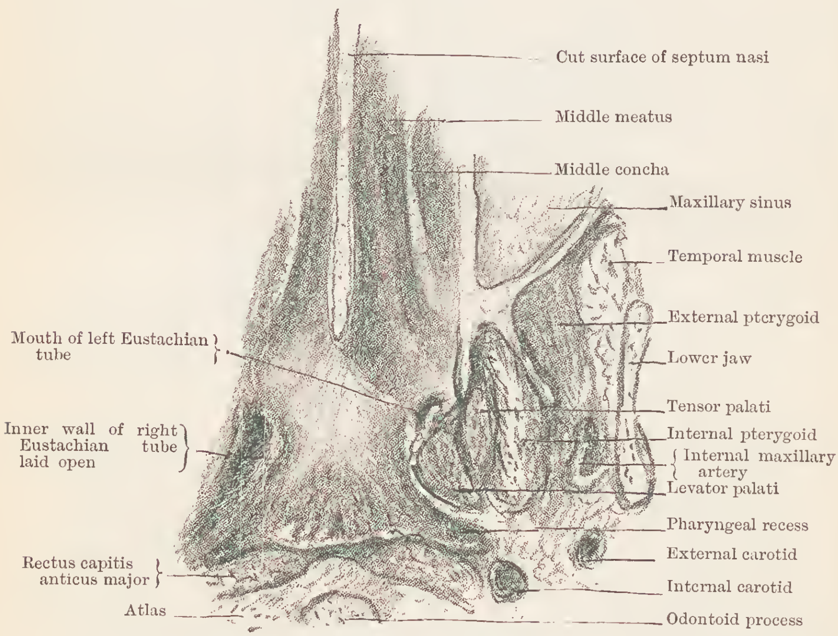


FIG. 509.—HORIZONTAL SECTION OF NASAL FOSSAE AND PHARYNX showing relations of Eustachian tube.

The Eustachian tube is an inch or more long, and leads from the tympanum to the pharynx. It begins in the lower division of the Eustachian orifice of the temporal bone, which is lined with thin mucous membrane, and is known as the osseous part of the tube. The whole of the rest is called the cartilaginous part, and is walled above and internally by cartilage, which is also folded for a short distance down on the outer side, while the floor and the greater part of the outer wall are formed of

fibrous membrane. Occupying the petro-sphenoidal groove, the roof of the tube, as it passes forwards, dips downwards from the base of the skull, and in its whole course the cartilaginous inner or posterior wall lies alongside of the outer wall of the pharynx, so as to permit of a horizontal section being made showing the recessus pharyngeus and Eustachian tube (which are the persistent hypoblastic portions of the first and second visceral clefts of the embryo) lying one close behind the other. The tube rapidly increases in depth and ends in the pharynx by an expanded opening, whence the old name *salpinx*. The expanded opening lies above the soft palate and behind the inferior meatus of the nose; it has a prominent internal or posterior margin and an angular roof, both stiffened by the thickened and elongated edge of the cartilage, which is here from a third to half an inch in height. Anteriorly the opening is smoothly continuous with the inferior meatus of the nose, and inferiorly it presents a convex floor continuous with the upper surface of the velum (Fig. 471). Consequently, a sound or catheter curved at the end, when introduced into the nose with the point downwards, has only to be carried back till it ceases to be supported by the hard palate, then turned so as to direct the point outwards, when it will slip into the Eustachian tube, avoiding with certainty the pharyngeal recess (fossa of Rosenmüller). The convexity of the floor of the opening is caused by the levator palati muscle, which, arising tendinously from the process between the Eustachian orifice of the temporal bone and the carotid canal, occupies a gradually widening groove formed by the floor of the tube all the way forwards (Fig. 277). The tensor palati is another muscle closely connected with the tube, inasmuch as it has fibres of origin from the whole length of the edge of the cartilage in the outer wall. Also, the salpingo-pharnygeus, when present, descends from the lower end of the edge of cartilage forming the inner lip of the pharyngeal opening. It is certain that all three muscles are contracted in the act of swallowing, and that the levator palati by increase of thickness during contraction raises the floor of the tube, while the tensor palati and salpingo-pharyngeus pull the edges of the cartilage downwards. Thus the shape of the tube is certainly altered in swallowing, but there is difference of opinion as to whether the alteration has a closing or opening effect, though the anatomical facts make it evident that any dilating influence of the tensor palati is exercised on the hinder and smaller part of the tube, while the levator closes the anterior orifice (Cleland, 1868). The lining epithelium of the mucous membrane is stratified columnar ciliated, which indicates that in ordinary circumstances the walls are sufficiently separate to allow of ciliary currents.

The Internal Ear.

The *internal ear* or *labyrinth* consists of a complex cavity situated within the petrous part of the temporal bone, and of membranous structures within it. The cavity is called the osseous, the continued structures the mem-

branous labyrinth; and each is divided into two parts, the vestibule and the cochlea, the division being situated opposite the internal auditory meatus, whose cribriform plate abuts against the vestibule posteriorly, and against the cochlea in front. The osseous labyrinth is lined with periosteum, and the fluid between the periosteum and the membranous labyrinth is called *perilymph.* The membranous labyrinth is lined with epithelium, and the fluid contained within it is distinguished topographically as *endolymph.*

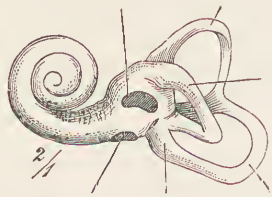


FIG. 510.—CAST OF LEFT OSSEOUS LABYRINTH, EXTERNAL ASPECT. (Pansch.)

The vestibule. The *osseous vestibule* consists of a cavity and three semicircular canals. The vestibular cavity has the fenestra ovalis in its outer wall, and communicates with the cochlea below and in front; the lower part of the communication being hollowed into a depression, *recessus cochleae*, internal to the fenestra rotunda. On its inner side in front is a depression, *fovea hemispherica*, corresponding with the cribriform plate of the internal meatus and separated by a crest (*crista vestibuli*) from a more elongated concavity, *fovea hemielliptica*, which involves the roof and internally receives the aqueductus vestibuli. Posteriorly it communicates with the semicircular canals. The three semicircular canals are one *superior*, another *posterior*, and the third *external.* The superior canal is an upright arch at right angles to the length of the petrous portion of the temporal, and the top of this arch is indicated on the upper surface of the bone by an elevation. The posterior canal lies close to the posterior surface of the bone, beneath which it can be seen in the young subject; and at its upper end it is joined to the superior canal by a short part common to both. The external canal is free at both ends from the others, is shorter than either of them, and is horizontal and deeply placed. Each canal has a bulbous swelling, the *ampulla*, at one end, and this, in the superior and external canals, is situated at their outer ends, and in the posterior at the lower end.

The *membranous vestibule* differs from the osseous in respect that, contained within the vestibular cavity there are two membranous vesicles, the utricle and the saccule. The *utricle* is the posterior and larger of the two vesicles, is broad from side to side and flattened from before backwards, and lies beneath the fovea hemielliptica. It receives the fine extremities of three membranous semicircular canals corresponding with the osseous semicircular canals in disposition and in each having an ampulla at one end.

The *saccule*, in front of the utricle, and smaller than it, is flattened from above downwards, and is circular as seen from above. It is separated from the utricle by a simple septum of small extent, and it communicates

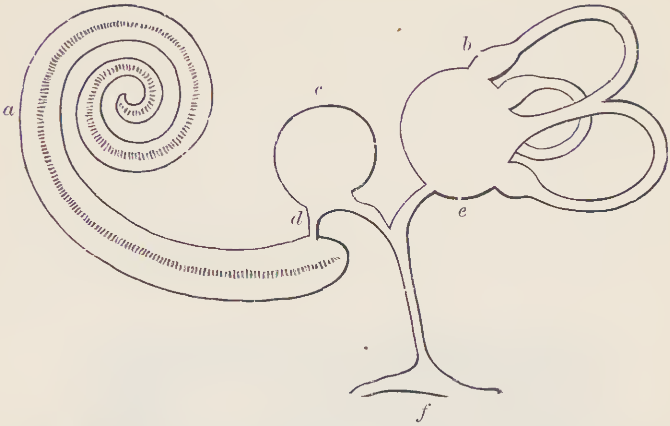


FIG. 511.—DIAGRAM OF MEMBRANOUS LABYRINTH. *a*, Canalis cochlearis; *b*, ampulla; *c*, sacculus; *d*, canalis reuniens; *e*, utriculus; *f*, sacculus endolymphaticus. (Pansch.)

with the canalis cochleae by a small duct, *canalis reuniens.* From saccule and utricle two other minute ducts pass back and unite at the commence-

FIG. 512.—AUDITORY CELLS, elongated epithelial cells and nerve-endings from macula acustica utriculi of child at birth. (After Retzius.)

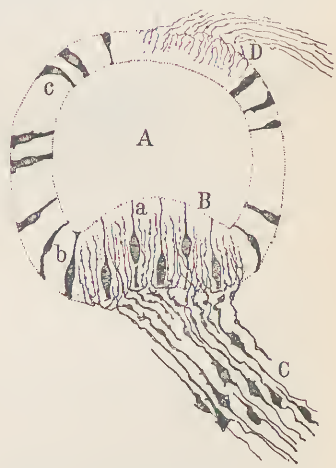


FIG. 513.—TRANSVERSE SECTION OF CRISTA ACUSTICA OF FOETAL RAT. A, Semicircular canal; B, crista; C, nervous bundle continued by bipolar cells; D, small nervous bundle ending in the upper part of the semicircular canal; *a*, bipolar epithelial cell; *b*, *c*, other epithelial cells. (Cajal.)

ment of the aquaeductus vestibuli, to form a single *ductus endolymphhaticus*, which dilates beneath the periosteum into a small vesicle, *sacculus endolymphaticus* (Böttcher), interesting as, together with the canalis reuniens, completing the continuity of the whole cavity of the membranous

labyrinth. The membranous vestibule presents, throughout, three walls, an outer or fibrous which is notably vascular, a structureless membrana propria, and an epithelium which is simple squamous except in the parts in which the auditory nerve terminates. The parts of the vestibule to which the nerve is distributed are five, namely, the macula acustica of the utricle, a smaller macula acustica of the saccule, and a crista acustica in the ampulla of each semicircular canal; and to each of these a separate bundle of nerve-fibres proceeds. The *maculae acusticae* are two patches marked by thickening on the lower parts of their respective vesicles, while the *cristae acusticae* are semilunar folds, one projecting inwards transversely in each ampulla. In all the five spots the epithelium is cylindrical, and presents auditory cells with hair-like processes projecting from the free extremity, while intermingled with them are elongated epithelial cells

FIG. 514.—SECTION OF COCHLEA OF PIG AT BIRTH. *a*, Canalis cochleae; *b*, scala tympani; *c*, scala vestibuli; *d*, basilar membrane and organ of Corti; *e*, membrane of Reissner; *f*, spiral ganglion. (Reichert.)

branched at their deep extremities and without hair-like processes. The auditory or hair-cells receive fine branches from nerve-fibres which lose their medullary sheaths as they pierce the membrana propria and spread out in other fine branches between them. On the surface of the auditory epithelium there is in each of the five patches a number of minute crystals of carbonate of lime (*otoconia*), and, superficial to the jelly in which these lie, an appearance of a membrane. The utricle and saccule lie nearer to the inner than the outer wall of the vestibule, and the membranous semicircular canals adhere to the convex sides of the arches of the osseous tubes containing them.

The cochlea. *The osseous cochlea* is a tube starting from the lower and fore part of the vestibule, and coiled spirally in the form of a snail's-shell. It begins at the fenestra rotunda and has the centre of the base of its spiral opposite the anterior part of the cribriform plate of the internal auditory meatus, while its apex or *cupola* abuts against the tympanum at

the commencement of the Eustachian tube, and the carotid canal is beneath it. The tube is about $\frac{1}{12}$th inch wide at its commencement and about half that width at the apex. The pillar of bone in the centre of the spiral is termed the *modiolus*; and from this there projects at right angles a spiral flange, *lamina spiralis*, extending into the tube along its whole length, but diminishing in breadth more rapidly than does the tube. It begins at the inner margin of the recessus cochleae in the floor of the vestibule, and ends at the cupola in a hook-like process, the *hamulus*. The modiolus is hollowed by canals containing the cochlear branches of the auditory nerve and internal auditory artery. The nerve-canals are united opposite the attachment of the lamina spiralis by a *spiral canal* for a spiral ganglion, and the branches of both vessels and nerves escape by a range of openings beneath the edge of the lamina spiralis.

Within the osseous tube there is a lining of periosteum continuous with that of the vestibule, and attached to it centrally and peripherally is the *cochlear part of the membranous labyrinth*, commonly called the *canalis cochleae*. The canalis cochleae is attached centrally to the lamina spiralis, and peripherally to a strip of the circumferent wall, and between these attached parts it is bounded by two membranes, called respectively the *basilar membrane* and the *membrane of Reissner*. The basilar membrane (together with the limbus to be afterwards described) separates it from a passage containing perilymph, the *scala tympani*; and the membrane of Reissner separates it from a similar passage, the *scala vestibuli*. At the base of the cochlea it presents a round cul-de-sac beyond the point where it receives the narrow canalis reuniens, and it is attached to the margin of the recessus cochleae so as to cut off the commencement of the scala tympani, and with it the fenestra rotunda, from the vestibule; but at the cupola there is a small space, *helicotrema*, $\frac{1}{20}$th inch across, between the end of the osseous tube, the hamulus and the blind end of the canalis cochleae; and here the scala tympani is continuous with the scala vestibuli which at the other end opens into the cavity of the vestibule above the canalis cochleae. Thus, the secondary membrana tympani closing the fenestra rotunda looks into a passage, the scala tympani, which only communicates with the vestibule circuitously by the helicotrema and scala vestibuli.

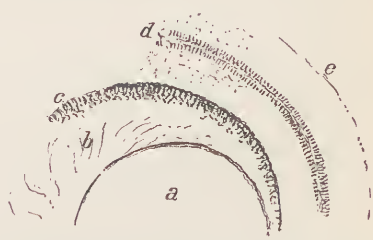


Fig. 515.—At the Summit of the Lamina Spiralis. *a*, Helicotrema; *b*, hamulus; *c*, crista spiralis; *d*, papilla spiralis; *e*, outer edge of basilar membrane.

The osseous lamina spiralis is prolonged outwards by a thickening of non-calcified substance, the *limbus*, which on the side next the scala tympani extends in a direct plane into the basilar membrane, but on the other rises into a convexity, the *crista spiralis*, covered with tooth-like processes, the outermost of which project as a lip, the *labium vestibulare*, overhanging a groove, *sulcus*

spiralis, which separates it from the *labium tympanicum* or part continuous with the basilar membrane. At the inner edge of the crista Reissner's membrane is attached, which is a delicate structure consisting of a fine layer of connective tissue and a simple squamous epithelium. The basilar membrane is stronger than the membrane of Reissner, and is transversely striated, being formed of fibres passing outwards to be attached to a structure lining the wall in a considerable breadth of both scalae, and usually called the *spiral ligament*, though described originally by Bowman as muscular, and admitted to be rich in spindle-shaped nucleated corpuscles. In consequence of the rapid diminution of breadth of the lamina spiralis, the basilar membrane is somewhat wider at the cupola than at the base. On the surface of the basilar membrane the epithelium of the canalis cochleae is modified to form a highly complicated structure, named from its discoverer *organ of Corti*. In the description of this I shall be guided to a great extent by Schwalbe.

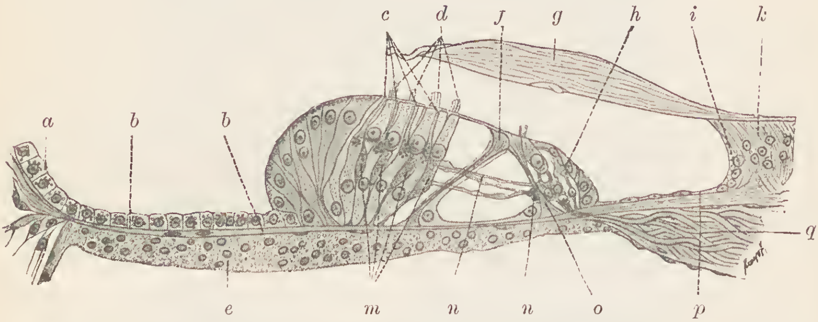


FIG. 516.—ORGAN OF CORTI IN VERTICAL SECTION. *a*, Cells of Claudius over cochlear ligament (Bowman's muscle); *b*, basilar membrane; *c*, outer support-cells (cells of Deiters); *d*, outer auditory hairs; *e*, lining of scala tympani; *f*, outer rods; *g*, membrana tectoria (Corti's membrane); *h*, inner support-cells; *i*, sulcus spiralis; *k*, labium vestibulare; *m*, outer auditory cells; *n*, nerve-fibres passing to them; *o*, inner rod; *p*, simple epithelium of sulcus spiralis; *q*, medullated nerves. (Böhm and v. Davidoff, after Retzius.)

The most prominent part of the organ of Corti is a strip of uniform breadth, the *papilla spiralis*; and between this and the free edge of the labium vestibulare of the limbus there is a strip, likewise of uniform breadth, in which the nerves pass obliquely up and enter the canal by a range of foramina counted by Kölliker as lying on the basilar membrane, but considered by Henle and more recent observers as belonging to the limbus. The foundation of the papilla spiralis is an outer and an inner row of strap-like structures called *rods of Corti*, which are specially developed epithelial elements of the deepest layer, and are of such breadth that three of the inner row are rather narrower than two of the outer. These are attached by thicker *footplates* to the basilar membrane, and, rising up, incline one to the other so as to include a roofed space or tunnel, and are then folded over and continued into *headplates* directed outwards, so that those of the inner rods bend over those of the outer rods and those of the outer rods fit into the hollow of the heads of the inner rods. On the inner or

modiolar side of the rods of Corti a simple epithelium lines the sulcus spiralis, and is prolonged outwards. Where it abuts against the inner rods the cells become elongated and arranged in more than one stratum. The outermost row of those placed superficially have free extremities lying close to the headplates of the rods, and each carry a row of short, straight hair-like processes. They are called the *inner auditory cells.* External to the outer rods the epithelial structures are more elongated, presenting in the basal turn three, and in the others four rows of *outer auditory cells,* separated and supported by other cells of elongated form, *cells of Deiters,* which are broad beneath them, and prolonged between them as narrow pillars. The outer auditory cells have straight hair-like processes arranged on the summit of each in a single curved line. Between the summits of the innermost row, elongated squamous processes extend from the headplates of the

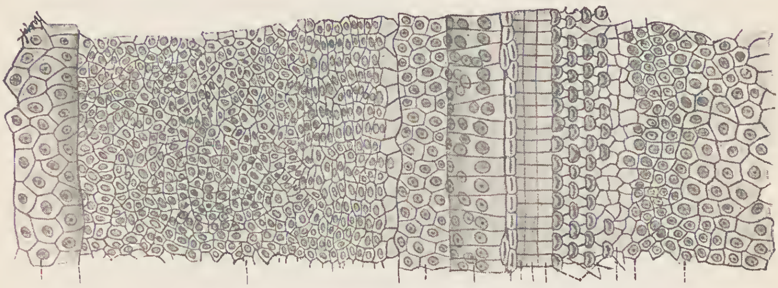


Fig. 517.—View of Surface of Organ of Corti in Child at Birth. *a*, Epithelium of membrane of Reissner turned over ; *b*, its attachment ; *c*, epithelium of limbus : *d*, labium vestibulare : *f*, sulcus spiralis : *g*, inner support-cells ; *h*, inner auditory cells ; *i*, *k*, ends of rods ; *l*, outer auditory cells ; *m*, phalanges ; *n*, outer cells of membrana reticularis ; *o*, cells of Hensen ; *p*, cells of Claudius. (Böhm and v. Davidoff, after Retzius.)

outer rods; and other squamous plates, *phalanges,* fit in between the extremities of these processes, and are interposed between the auditory cells of the second row, while another row similarly fits in between the ends of the first phalanges and separates the third row of auditory cells one from another. These phalanges are connected with the summits of the cells of Deiters, but are separable from them at the same time that they retain their connection one with another so as to form the *membrana reticularis,* which is continued out into an unbroken layer of cells (*of Hensen*) composing the outer limit of the papilla spiralis. Beyond this the part of the basilar membrane uncovered by the papilla spiralis has a simple epithelium of large cubical cells (*of Claudius*).

The whole papilla spiralis is covered over by a remarkable membrane called *membrane of Corti* (membrana tectoria), which lies free in the canalis cochleae. It is attached to the crista spiralis close to the membrane of Reissner, and is free externally, arching over the organ of Corti, but slightly curled upwards at the margin, and presents no structure save a distinct oblique striation.

The *nerves* of the cochlea are arranged in the canals of the modiolus in

a roll whose turnings correspond with those of the tube, those for the cupola being in the centre; and, reaching the spiral canal, they enter at the *spiral ganglion.* This ganglion consists of bipolar cells interrupting the nerve-fibres. Emerging from this, the nerve-bundles pass obliquely through the limbus, flattened at first, but becoming cylindrical where they perforate. There they lose their medullary sheaths, and, as varicose axis-cylinders, are prolonged both to the inner and outer parts of the papilla, and in longitudinal directions beneath the rods of Corti; but further observation is desirable as to their precise method of distribution to the auditory cells.

The *arteries* are branches of the internal auditory, and while in the modiolus form a spiral row of convolutions, *glomeruli arteriosi* of Schwalbe, and supply also the spiral ganglion. The returning blood is gathered to a spiral vein opposite the scala tympani. A network of vessels surrounds the whole tube, but is much closer than elsewhere on the outer wall of the canalis cochleae, internal to the spiral ligament, and in this a vessel has been described as running spirally, the *vas prominens.* Also vessels pass out into the limbus and the basilar membrane, and one running along beneath the papilla spiralis has been described as vas spirale. But the outer part of the basilar membrane is non-vascular.

Development of the Ear.

The external, middle and internal ear are in great measure developed independently. The internal ear takes origin from the auditory pit (p. 98), which, after closure, is called the *otic vesicle,* whose place of entrance into the cranium becomes lost to view, save in elasmobranch fishes, where in the adult it pierces the roof. The vesicle presents a neck and a sac. The lower part of the sac is converted into cochlea and the upper part into vestibule and semicircular canals, while it is alleged that the neck remains as the endolymphatic sac and duct, though further investigation is desirable both on this subject and on the origin of the semicircular canals. The formation of the canalis cochleae by retreat of the basilar membrane and membrane of Reissner from the osseous wall was pointed out many years ago by Huschke. W. His, Jun., finds at an early date a ganglion not confined to the formation of the spiral ganglion of the cochlea, but going to all the parts of the labyrinth which afterwards receive nerve-terminations, and including cells in connection with the facial nerve to form the geniculate ganglion.

The tympanic cavity has been already stated (p. 98) to be the hypoblastic part of the first branchial cleft, while the external meatus is the epiblastic part of the same, and the membrana tympani is in the position where epiblast and hypoblast meet in this cleft in the embryo. The origin of the ossicles has been already mentioned (p. 246). The expanded part of the pinna makes its appearance before the closure of the vertebral end of the first branchial cleft, in the form of a series of definite prominences behind, above and in front of the cleft.

VISCERA.

THE VISCERAL CAVITY.

Having regard to the skeleton, the body may be said to present two great cavities, the *neural* and the *visceral*.

The neural cavity contains the great centre of the nervous system, the cerebro-spinal axis, and is divisible into two parts, namely, first, the cranial cavity, expanded and irregular in form, containing the likewise expanded and irregular encephalon, and, secondly, the regularly segmented spinal canal containing the regularly constructed spinal cord. The neural cavity originates in the early embryo from the medullary groove, which becomes closed in by the meeting of the medullary folds in the middle line (p. 90), and is specially characteristic of the vertebrata.

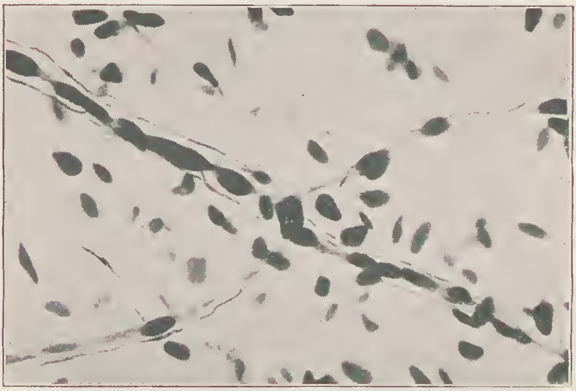


Fig. 518.—Peritoneal Membrane denuded of Endothelium, showing capillaries, nucleated single nerve-fibres and amoeboid corpuscles. The capillaries contain blood. Photographed from carmine preparation.

The visceral cavity, in the widest sense of the term, is the space occupied by viscera, and bounded more or less completely by skeletal and muscular walls, and exists not only in the thorax, abdomen and pelvis, but also in the head and neck as well; the pharynx, oesophagus, tongue, larynx, trachea and thyroid body being all developed in connection with the same mucous membrane as lines the abdominal part of the alimentary canal. The term visceral cavity is, however, more frequently used in a more restricted sense, and applied to the thorax, abdomen and pelvis, the regions characterized by containing large serous membranes. Not only are these membranes embryologically derived from a single pleuro-peritoneal sac or *coelom*, corresponding with the coelom or *body-cavity* of invertebrate animals, but the coelom is, in early embryonic life, found even in the head, in at least elasmobranch fishes (p. 93). In further development the common sac undergoes subdivision, the pericardium and the two pleural sacs being completely separated from the peritoneum,

and, in the male of the human species, two other small portions being likewise closed off, namely, the tunicae vaginales which cover the testes. All the divisions are transparent membranes with delicate simple squamous covering. They have a vascular network proper to them, are supplied with nerves (Fig. 518), and become painful when inflamed. In man, as in all mammals, the visceral cavity is completely divided by the diaphragm into a thoracic cavity containing the heart and lungs covered respectively with pericardium and pleurae, and the abdominal cavity lined with peritoneum and extending into the pelvis.

(*A*) The Thoracic Cavity.

The thoracic cavity is mainly occupied by the heart and lungs, each with its own serous sac. Those of the lungs are termed the *pleurae*, and

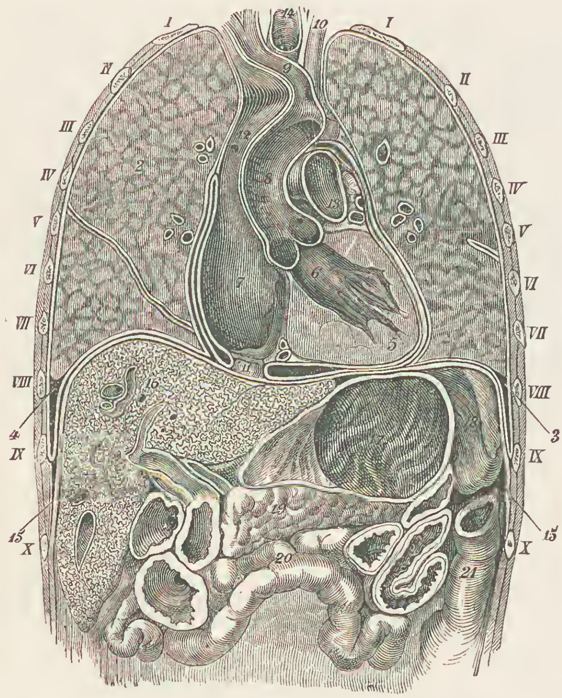


Fig. 519.—Frontal Section of Frozen Body of Female of 40 Years. 1, 2, Lungs; 3, 4, costo-phrenic spaces; 5, left ventricle; 6, aortic cusp of mitral valve; 7, right auricle; 8, aorta; 9, innominate artery; 10, left common carotid; 11, vena cava inferior; 12, vena cava superior; 13, pulmonary artery; 14, trachea; 15, diaphragm; 16, liver; 17, stomach; 18, spleen; 19, pancreas; 20, loops of small intestine; 21, descending colon. (Luschka.)

that of the heart is, together with an investing fibrous pouch, called the *pericardium*. To the interval between the two pleurae the name *mediastinum* is given, and it is occupied in its principal part (the *middle mediastinum*) by the pericardium and its contents, as well as great bloodvessels and the bifurcating trachea, while superficial to it the *anterior mediastinum* is dis-

tinguished, and behind is the *posterior mediastinum*, in which the oesophagus is placed.

The pericardium consists of two membranes, a fibrous and a serous. The *fibrous pericardium* is a strong white fibrous bag, widest below, where it is attached to the central tendon of the diaphragm, in front and behind to its margin, and on the right side external to the opening for the vena cava inferior, while on the left side it encroaches on the muscular fibres. Superiorly it is connected with the outlets of the pulmonary veins, and

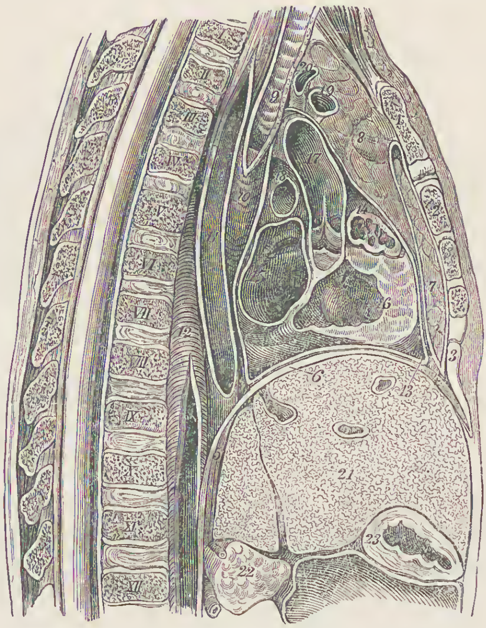


FIG. 520.—SAGITTAL SECTION OF THORAX AND EPIGASTRIUM OF FROZEN BODY OF INFANT 1½ YEARS OLD. 1, 2, 3, Sternum; 4, 5, diaphragm; 6, its central tendon; 7, right lung crossing the mesial plane; 8, thymus; 9, 10, trachea and left bronchus; 11, 12, oesophagus and aorta in posterior mediastinum; 13, pericardium; 14, right auricular appendix; 15, left auricular cavity; 16, right ventricle; 17, ascending aorta; 18, right pulmonary artery; 19, left innominate vein; 20, innominate artery; 21, liver; 22, pancreas; 23, stomach. (Luschka.)

also with the vena cava superior and the pulmonary artery, but its strongest fibres are prolonged high on the front of the ascending aorta. The *serous pericardium* presents a parietal and a cardiac part. The parietal part clothes the tendinous surface of the diaphragm, and lines the fibrous pericardium. The cardiac part is continuous with the parietal by two distinct folds, one of which invests the ascending aorta and the pulmonary artery in a tubular sheath, while the other, behind, separated from the arterial sheath by a passage called the *transverse sinus*, is connected with the great veins and with the auricles, namely, with the right edge of the right auricle between the superior and the inferior vena cava, and with the upper edge of the left auricle between the right and left superior pulmonary veins, as has been more particularly described at p. 409.

The pleurae present each a parietal and a pulmonary part. The *pulmonary part* closely invests the lung, and dips in between the principal lobes, the three of the right, the two of the left. It surrounds the root of the lung, lying in contact with it above, behind and in front, but forming below it a fold with an anterior and posterior layer, *ligamentum latum pulmonis*, reaching down towards the diaphragm, and attaching the inner surface of the lung to the pericardium. Although thin, the pleura is capable of being separated continuously from the surface of the lung. It has a large number of elastic fibres in its substance, and has independent branches of vessels ramifying through it from the neighbourhood of the root. It is subject also, especially along the sharp lines separating the surfaces, to pigmentary deposits such as are found in the pulmonary substance.

The *parietal part* is applied to the costal walls, the diaphragm and the pericardium, and is arched above the level of the first rib, so as to come in contact with the subclavian artery and vein behind the clavicle; the right pleura usually reaching slightly further up than the left. The diaphragmatic floor is placed very decidedly on a higher level on the right side than on the left, but it may be mentioned, as a point which in former years often came under my notice in giving clinical instruction, that the left floor is more easily raised by pathological diminution of the lung above it than the right, owing to the stomach being raised more easily than the liver. The diaphragmatic and costal pleura are continued down as far as the attachments of the diaphragm allow, and are in contact one with the other below the level of the edge of the lung for a distance which increases in expiration, and decreases in inspiration, and is known as the *costo-diaphragmatic* or *costo-phrenic space.*

The posterior mediastinum, or the space between the pericardium and the vertebral column, is bounded on each side by pleura, the right pleura coming further forwards on the bodies of the vertebrae than the left, which leaves the column sooner, and, passing forwards, clothes the side of the descending aorta. Beneath the pleura the azygos veins lie on the bodies of the vertebrae, and on the right side the great vena azygos passes forwards above the root of the lung to open into the superior vena cava. The oesophagus lies in the middle of the posterior mediastinum, with the aorta descending at first on its left, and afterwards behind it; and the thoracic duct lies between the oesophagus and the right vena azygos till, near the upper part of the thorax, it crosses the middle line obliquely.

The anterior mediastinum is bounded on each side by the reflection of the pleura from the costal wall to the pericardium. The line of reflection on each side comes nearly into contact with its neighbour in the mesial plane opposite the second intercostal space; but from this level that of the right pleura is continued downwards vertically while that of the left pleura slopes downwards and outwards in such a direction as to leave the pericardium at the apex of the heart in contact with the thoracic wall to

the left of the sternum. The part behind the manubrium of the sternum preserves in the young subject vestiges of the thymus gland, which in the adult are reduced to a small quantity of rather deep yellow fat.

(*B*) The Abdominal Cavity.

The abdominal cavity contains the digestive tract from the stomach onwards, and two large glands connected with it, namely, the liver and

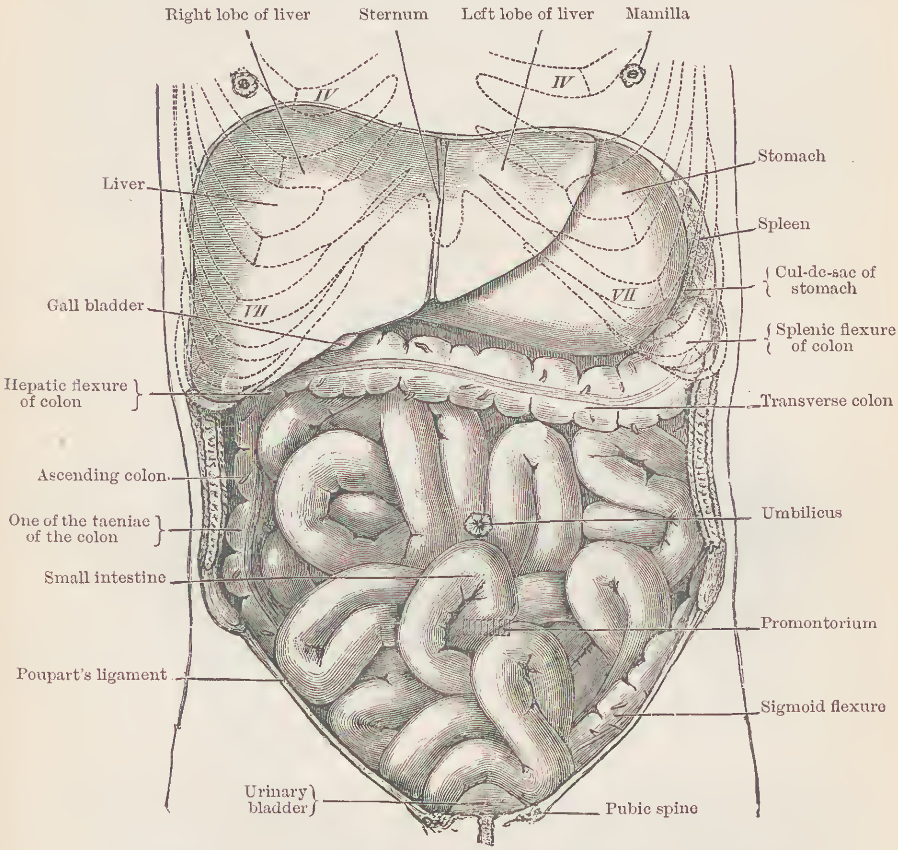


Fig. 521.—Abdominal Viscera. The great omentum has been removed. (Pansch.)

pancreas; the spleen and the suprarenal capsules which are structures belonging to the group called ductless glands; and also the kidneys, the urinary bladder and the reproductive organs. It is divisible into abdomen proper and pelvis; but the pelvis, or region below the level of the brim of the true pelvis of the skeleton, is only the lower part of the cavity of the abdomen, undistinguished from it by any partition, and lined by a continuation of the same serous membrane, the peritoneum. To enable the regions of the abdomen proper to be explicitly expressed, three zones are recognized.

The middle one is the interval between the levels of the lower ribs and the crests of the iliac bones, and its lateral parts are called the *lumbar* regions, while its mesial part is termed *umbilical.* The lateral parts of the zone above are called *hypochondriac*, and its mesial part is the *epigastric* region. In the inferior zone the mesial part is called *hypogastric*, and the lateral parts *iliac.* Any particular spot in the abdomen can always be explicitly registered by reference to one or more definite points in the skeleton.

The peritoneum, the serous membrane lining the abdomen, is thrown into a number of complicated folds, partly owing to the number of viscera to which it is applied, and partly to the great elongation and consequent winding of the digestive tube. Those folds which unite the small intestine, colon and rectum to the parietes are termed *mesentery*, *mesocolon* and *mesorectum*; those which unite other viscera with the parietes are called *ligaments*; and those which unite one *viscus* with another are called *omenta.*

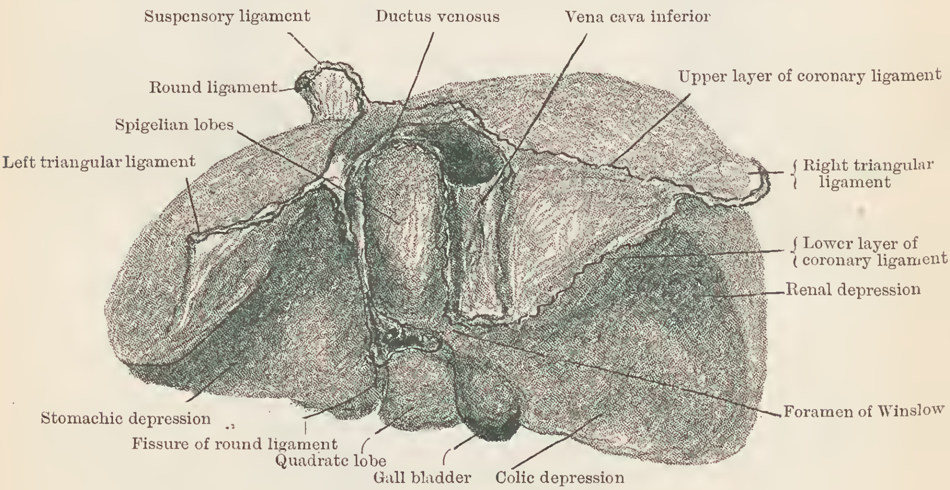


FIG. 522.—LIVER AND ITS LIGAMENTS FROM BEHIND.

The part which lines the anterior wall of the abdomen is thrown at the lower part, above the brim of the pelvis, into three depressions by two cords which run upwards to the umbilicus, one from either side of the urinary bladder, namely, the obliterated hypogastric arteries; and in those instances in which the deep epigastric artery happens to lie distinctly external to the obliterated hypogastric artery an additional small depression is formed on each side between the two vessels. Oblique inguinal hernia pushes its way by deepening the depression external to the deep epigastric artery, while direct inguinal hernia passes down internal to the deep epigastric, and either internal or external to the obliterated hypogastric according as that cord corresponds with the deep epigastric artery, or is separated from it by a peritoneal depression above the umbilicus. A single

cord, the obliterated umbilical vein, ascends to the under surface of the liver, which it reaches at the notch dividing the right from the left lobe; and the peritoneum reflected from the abdominal wall round this cord is thrown into a fold called the *suspensory* or *falciform ligament* of the liver, while the obliterated vein is sometimes called the *round ligament* of the liver. On each side of the suspensory ligament the peritoneum passes backwards, clothing the diaphragm and the dorsum of the liver as far back as the posterior border of the liver; and it likewise turns round the anterior edge of the liver and closely invests its under surface, extending on the right and left side so far back that the reflection below comes in contact with the reflection above, so as to form a pair of folds between liver and diaphragm called the *right* and *left triangular ligaments.* Between these the layers of peritoneum above and below the liver are separated by the thick posterior border of the liver lying in direct contact with the diaphragm, and together constitute the *coronary ligament.*

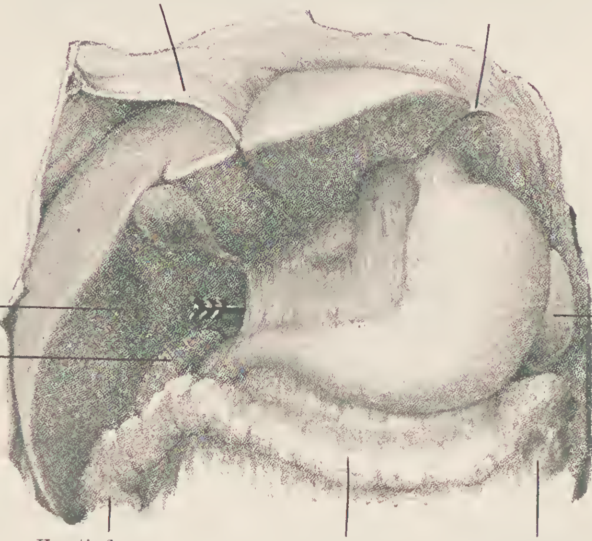


FIG. 523.—CONNECTIONS OF LIVER AND STOMACH. A broad arrow is placed in the foramen of Winslow, behind the gastro-hepatic or small omentum. To the right of the oesophageal opening of the stomach the gastro-phrenic ligament is seen. (Alexander Macphail, M.B.)

But, while at each side the peritoneum extends back under the liver to its posterior border, it is reflected in the middle at the portal fissure away from the liver to the duodenum and stomach, and opposite the right end of the portal fissure turns in behind the structures entering and leaving that fissure, so as to form a constricted aperture, the *foramen of Winslow,* which, followed to the left, expands into the *smaller sac of the peritoneum.*

The foramen of Winslow is usually just large enough to admit a finger. It has above it the only lobe of the liver invested by the smaller sac of

peritoneum, namely, the *lobulus Spigelii*; behind it the inferior vena cava; beneath it the duodenum, and in front of it the gastro-hepatic omentum.

The gastro-hepatic or *small omentum* is the peritoneal fold connecting the pylorus and commencement of the duodenum with the portal fissure of the liver, and contains within it the bile duct to the right, the hepatic artery to the left, and the portal vein between and behind these, besides nerves and lymphatics. From the liver and diaphragm the peritoneum extends downwards over the stomach as far as the inferior border or great curvature, and beyond this it is continued onwards as the superficial layer of a pendulous fold, sometimes disposed over the surface of the small intestines, and sometimes crumpled along the lower border of the transverse colon, the *gastro-colic* or *great omentum.* When this is cut a little below the stomach, the interior of the smaller sac of the peritoneum is laid bare, and the gastro-colic and gastro-splenic omenta, the splenic ligament and the transverse mesocolon can be studied.

The smaller sac of the peritoneum (*sac of the great omentum*), commencing at the foramen of Winslow, and passing towards the left between the Spigelian lobe of the liver and the origin of the hepatic artery, expands behind the stomach. It extends up to the diaphragm, and, lying above the stomach in contact with the general peritoneum, forms with it the *gastro-phrenic* ligament which, on the right is continuous with the gastro-hepatic or small omentum. Anteriorly the small sac covers the posterior surface of the stomach and commencement of the duodenum; posteriorly it invests the anterior surface of the body of the pancreas, reaching, on the left, even to the spleen, a small portion of which, as much as half an inch in diameter, it may invest in front of the hilus. Below the pancreas it leaves the posterior wall of the abdomen, and descends to the anterior surface of the transverse colon, and between this and the stomach it is laid in contact back to back with the pendulous fold of the general peritoneum already traced.

The gastro-colic or *great omentum* is, therefore, a greatly elongated fold formed by a layer of the greater and a layer of the smaller sac of peritoneum placed back to back; but, as it lies in its natural and pendulous position it presents four layers, the anterior and posterior belonging to the general peritoneum, while the intervening two are the anterior and posterior walls of the smaller sac gliding one on the other. The layers belonging to the greater and smaller sacs are not only applied very firmly to one another, but are in many places so attenuated and perforated as to present the appearance of a net; while, in the bars between the perforations, adipose tissue is often very considerably developed.

The gastro-splenic omentum is formed by the peritoneum extending from the front of the stomach to the front of the hilus of the spleen, and the smaller sac extending from the posterior surface of the stomach to touch the spleen. The spleen is not only attached thus to the stomach, but also to the diaphragm, the latter connection forming the *spleno-phrenic*

ligament. This consists of two layers, one of them belonging to the smaller sac, and reflected from the surface of the pancreas and upper part of the surface of the left kidney, the other belonging to the greater sac or general peritoneum, and continuous at the posterior margin of the hilus with the peritoneal investment of the spleen. The spleno-phrenic ligament contains the splenic vessels between its layers, and superiorly is continued to the left side of the oesophageal opening of the stomach by what may be called a *left gastro-phrenic ligament.*

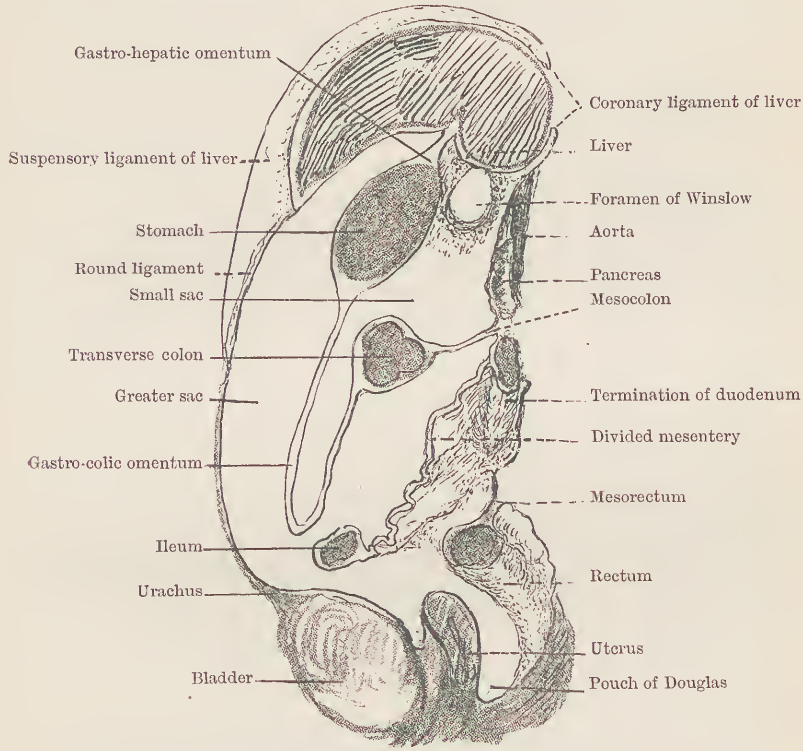


FIG. 524.—DIAGRAM OF PERITONEAL FOLDS in mesial section.

The transverse mesocolon, in the greater part of its extent, is the continuation backwards of the layers of the greater and smaller sacs of the peritoneum which form the great omentum. The layer from the smaller sac invests the front, and that from the greater sac the back of the transverse colon, and the two layers meeting again extend back to the abdominal wall at the lower border of the pancreas. But beyond the left border of the smaller sac a certain extent of the transverse colon may be separated from the posterior wall by mesocolon formed altogether by the general peritoneum; and beyond the right border of the smaller sac the transverse colon crosses the duodenum with the general peritoneum surrounding it more or less completely.

The hepatic and splenic flexures of the colon are only partially surrounded with peritoneum, and above the hepatic flexure the peritoneum is in contact with the upper part of the right kidney.

At the right and left sides of the posterior wall of the abdomen the ascending and descending colon are retained in position by the peritoneum failing, as a rule, to invest them completely; but portions of mesocolon may exist in connection with both one and other. The vermiform appendage of the caecum has always a mesenteric fold. Below the descending colon the sigmoid flexure is attached by an elongated mesentery continuous below with the mesorectum which intervenes between the upper part of the rectum and the sacrum.

The mesentery, properly so called, is a fold of the peritoneum between the posterior wall of the abdomen and the whole length of the jejunum and ileum. At its intestinal edge it has the length of the intestines round which its layers are prolonged, but at the parietal edge it has a short straight line of attachment extending from where the transverse mesocolon crosses the mesial plane as far as the position of the caecum in the right iliac fossa, altogether a distance not more than five inches long. At its commencement it lies on the last part of the duodenum in such a manner as to leave a detectable portion to the right, clothed in front with peritoneum between mesentery and transverse colon, while half the breadth of the last two inches can invariably be seen on the left (Fig. 551).

Within the *pelvis* the peritoneum *in the male* presents a *recto-vesical pouch* descending between the bladder and rectum down to near the entrance of the ureters into the bladder. On each side a linear prominence is formed by the obliterated hypogastric artery passing forwards; and it is customary to distinguish the portions of peritoneum extending to the bladder as five *false ligaments of the bladder*, the parts below the hypogastric arteries constituting the two *posterior ligaments*, those above and outside them being the two *lateral ligaments*, and the mesial part above and between them being the *anterior* false *ligament*.

In the female the uterus and vagina lie behind the bladder, and the peritoneum covers the posterior aspect of the uterus and upper part of the vagina, thus forming a *recto vaginal pouch* (*pouch of Douglas*). It also clothes the greater part of the front of the uterus, and on each side is extended so as to form the *broad ligament of the uterus* (*ala vespertilionis*). This surrounds the Fallopian tube, attaching it by a wide fold to the pelvic wall, and anteriorly invests partially the round ligament of the uterus, while posteriorly there comes off from it another fold which at its free edge completely surrounds the ovary, and less completely the round ligament of the ovary. The openings of the fimbriated extremities of the Fallopian tubes offer the only exception in mammalia to the rule that serous membranes become in process of development completely closed sacs; but it is to be remembered that in the lower vertebrates abdominal pores occur.

THE DIGESTIVE ORGANS.

Under this head may be conveniently included the alimentary canal and the glands which open into it. The divisions of the alimentary canal are the mouth, pharynx, oesophagus, stomach and intestine. The teeth, though situated within the mouth, are structures of such a special kind that it is better to describe their structure and development before proceeding to the description of the soft structures. Of glands limited in number and so considerable in size as not to take part in the formation of the walls of the alimentary canal, one set, the salivary, open into the mouth, while the only others, the pancreas and the liver, open into the duodenum which is the uppermost part of the small intestine.

THE TEETH.

In the human subject the permanent teeth are thirty-two in number, eight on each side in each jaw, which it is customary to enumerate from before backwards, namely, first and second incisors, one canine or eye-tooth, first and second bicuspids or premolars, and first, second and third molars. The temporary or milk-teeth are twenty in number, five on each side in each jaw, namely, two incisors and a canine, displaced by the corresponding permanent teeth, and two milk-molars displaced by the bicuspids. The molars of the permanent set are not preceded by any temporary teeth.

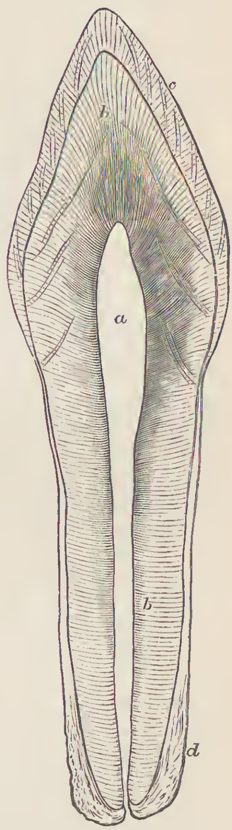


FIG. 525.—INCISOR TOOTH, vertical section. *a*, Pulp cavity; *b*, dentine; *c*, enamel; *d*, crusta petrosa. The lines on the enamel indicate the direction of coloured bands; those on the dentine are the concentric or contour lines of defective mineralization.

Each tooth consists of a *crown* and a *root*, with a slight constriction where these meet, called the *neck*. The crown presents in the different teeth differences in the number of *cusps* or prominences at the summit, while the root presents one or more *fangs*. The hard structure consists mainly of dentine, but on the crown this is covered with *enamel*, and on the root with a certain amount of *crusta petrosa*. In the interior there is left a hollow, the pulp-cavity, communicating, at the tip of each fang, with the outside, by a foramen through which pass an artery, a vein and a nerve; and in the adult, the contained *pulp* consists principally of branches of vessels and nerves, with a small amount of delicate connective tissue supporting them, and is surrounded by a continuous layer of corpuscles called *odontoblasts*, belonging to the dentine.

Dentine is a texture slightly harder than compact bone and yielding about 72 per cent. mineral matter, principally phosphate of lime. It presents, in a mineralized gelatiniferous matrix, tubules lying side by side, and extending from the pulp-cavity to the circumference, bifurcating sometimes in their course, and dividing into branches close to the surface. They also give off exceedingly fine lateral branches easier seen in young teeth than in the adult. They present in their course a large or primary, and a finer or secondary set of undulations in the vertical plane. The secondary undulations are small and irregular, but the primary are regularly disposed so as to throw the tubules in most places into a letter S curve, only to be seen in longitudinal sections and causing a satin-like play of light. The walls of the tubules resist the action of solution of caustic potash or strong acid longer than the matrix around, and may be more or less completely liberated. The lumen of the larger tubules may average about $\frac{1}{10000}$th of an inch in diameter. In dried teeth the tubules are filled with air, but in the fresh state they contain a thread, the *dentine-fibre.* In sections through dentine and pulp, the dentine-fibres are seen to be continuous with processes from the layer of corpuscles surrounding the pulp, namely, the odontoblasts. The *odontoblasts* are elongated corpuscles arranged in a single continuous layer and sending processes, more than one from each, into the dentine canals. They can be observed from the earliest period of the development of the dentine; and as the dentine is originally formed first at the surface, and grows inwards at the expense of the pulp, the proof is complete that the odontoblasts are the dentine-corpuscles, and that they elongate their processes as these become embedded in dentinal matrix; thus differing from bone-corpuscles in being pushed in front of the calcifying matrix, instead of becoming completely embedded. This being the case, it is plain, as I have pointed out (*Nature*, 1890), that while bone-corpuscles have only a limited individual existence, the same odontoblasts last during the whole life of the tooth. As age advances the pulp is more and more encroached on, to almost complete disappearance, and the tubules in the later dentine become irregularly disposed. Wearing away of the crown, such as happens in some persons and races more than in others, promotes growth inwards of the dentine, and in the centre of the worn surface the newer dentine is more deeply coloured.

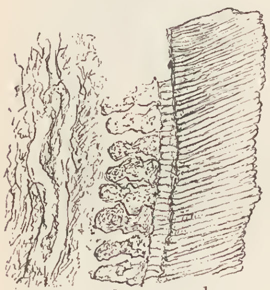


Fig. 526.—Longitudinal Section of Pulp and Dentine. *a*, Vessels, nerves and stroma of pulp; *b*, odontoblasts; *c*, dentine fibres.

Where the dentine is covered with enamel the tubules pass occasionally out to be continued a little distance into the enamel, sometimes in a dilated form. Where it is covered with crusta petrosa, tubules may also sometimes be followed out into that substance, and, very generally, there is a *granular layer* (*of Purkinje*) underneath the crusta petrosa, which owes

its appearance to small spaces, often communicating one with another and with the tubules, and sometimes taking the form of interstices between aggregated globules of matrix, the globules varying in size but averaging about $\frac{1}{2000}$th of an inch in diameter. On this account they have been described as *interglobular spaces.* But these are not to be confounded with much larger spaces of similar interglobular appearance arranged in conical sheets, so as to form concentric lines in horizontal sections, particularly of the crown.[1] The latter are bounded by much larger lobes and neither communicate with the tubules nor affect their course, and though less densely mineralized than the rest of the matrix, are so filled up that they cease to exist in decalcified sections. Some of the concentric lines show

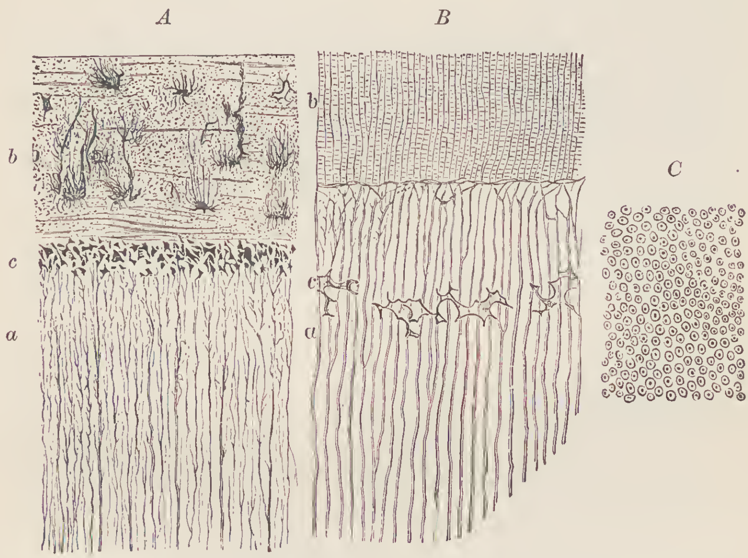


FIG. 527.—SECTIONS OF HUMAN TOOTH. *A*, *a*, Dentine; *b*, crusta petrosa; *c*, granular layer; *B*, *a*, dentine; *b*, enamel; *c*, spaces forming a line of contour or concentric line; *C*, dentine canals in transverse section. (Toldt.)

this deficient mineralization in less definitely bounded patches, while yet others are caused by a finely granular disposition of mineralized particles, and such granular lines are the rule in some non-mammalian teeth. Separate small globules of mineralization occur close to the pulp, both in old teeth and in the first commencement of dentine in development. In decalcified dentine, lamination and fibrillation, similar to what occurs in bone, has been noticed (Sharpey).

Enamel is much the hardest texture in the body. Different analyses have yielded from 2 per cent. to $3\frac{1}{2}$ per cent. organic matter; while the remainder consists of mineral salts, principally phosphate of lime. It

[1] These are the *contour lines* of Owen, the *incremental lines* of Salter. The only objection to the first name is that they approach the surface at their extremities. It is perfectly certain that they have nothing to do with increment of any sort.

consists of hexagonal prisms about $\frac{1}{5000}$th of an inch in diameter, extending vertically from the dentine to the surface, and packed closely together, for the most part parallel, but sometimes exhibiting groups irregularly crossing one another as if crushed down to a slight extent by vertical pressure. They can be isolated to some extent by the action of hydrochloric acid, when they can be seen more distinctly than in continuous sections to have a regular transverse striation, due neither to varicosity nor pigment. Superficially the enamel is overlaid by a continuous structureless layer, separable by the action of hydrochloric acid, *Nasmyth's membrane*, which at the base of the crown ends in the crusta petrosa. The inner ends of the enamel-prisms impress the surface of the dentine, and their outer ends can sometimes be seen forming a hexagonal pattern when examined with a high power. But with a simple lens there can always be detected on the surface of uninjured permanent teeth another pattern, which has apparently escaped notice, namely, a fine ripple-mark of horizontal lines, interesting in connection with the exaggerated and irregular ridges which occur pathologically. The milk teeth have no such lines on their enamel, but may present minute and shallow pits. Coloured bands often occur in the enamel, crossing the prisms in such a direction as to cause lines seen in longitudinal sections to extend upwards and outwards from the dentinal to the free surface.

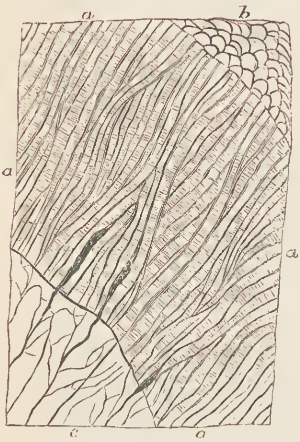


FIG. 528.—SECTION THROUGH ENAMEL OF ELDERLY SUBJECT. *a*, Enamel prisms; *b*, their free extremities in perspective; *c*, dentine, with some of its tubes prolonged into spaces between the enamel prisms.

Crusta petrosa or *cement* is much less regular, both in disposition and structure, in the human subject, than dentine and enamel. To understand it properly it should be looked at in teeth such as those of the horse, with deep recesses on the crown, when it will be seen to fill up the recesses lying superficial to the enamel, and to coat the fangs with regularly disposed laminae of osseous tissue. It is softer than dentine. In the human subject it occurs only on the root, and is found most abundantly at the tips of fangs, between the fangs of molars, and on the grooves of double fangs. Where thickly deposited, it has lacunae and canaliculi irregularly scattered, and usually ragged and irregular in form. It frequently shows lamination, and in portions exhibits minute spaces like the smallest of those in the granular layer of dentine; also lines may be seen at right angles to the dentine and the lamination. It is most abundant in old teeth.

The permanent teeth. *The incisors* have chisel-shaped crowns and single-fanged roots. The summit of the crown when unworn is undulated, showing three slight elevations separated by depressions which are prolonged down on the superficial aspect; on the lingual aspect it presents a slight depres-

sion where it begins to flatten out to the summit. The single-fanged root tapers, without constriction, at the neck, and is broader from front to back than from side to side. The upper incisors are larger than the lower. The first upper is the largest of all and has the longest fang; the first lower is the smallest of all and has the shortest fang. The second upper incisor is always unsymmetrical, being prolonged as far as the edge of the first incisor on the one side, and on the other bevelled to allow the lower canine to fit between it and the upper canine. Normally the summits of the lower incisors are overlapped by the upper; and deviation from this is the essence of the peculiarity of jaw called "underhung."

FIG. 529.—PERMANENT TEETH. *a*, First upper incisor from labial and lingual aspects; *b*, upper canine from labial and lingual aspects; *c*, upper bicuspid from dental and buccal aspects; *d*, upper true molar showing its single inner and two outer fangs; *e*, crown of the same; *f*, left lower true molar from buccal aspect.

The canine or *eye-teeth* have the middle of the three elevations seen on the summits of the incisors greatly exaggerated, and the depression on the lingual aspect less marked. The root is single-fanged[1] and both longer and stronger than the fangs of the adjacent teeth, causing projection of the walls of their sockets, so as to form the outer boundary of the incisor fossa in both upper and lower jaw. In the most regular dentition both the summits and labial surfaces of the canines are in line with the other teeth, but they often project both upwards and outwards.

The bicuspids or *false molars* have each an outer and an inner cusp on the crown, the outer somewhat the larger. Their roots are deeply grooved in front and behind, and most frequently end in a single extremity, but are often somewhat bifid, and this bifidity is more frequent in the first than in the second or hinder of the two.

The molars of the upper and lower jaws, though somewhat similar in the form of their crowns, are easily distinguishable. The upper molars have four cusps, two outer and two inner, and have three fangs, two of them placed one in front of the other on the side next the cheek, cylindrical in form; and a third on the lingual side, broader from before backwards at the base, but rapidly becoming cylindrical, and lying side by side with the hinder of the two outer fangs. The lower molars have a fifth cusp behind the others, and have two broad fangs one in front of the other, each with two foramina at the extremity, and liable to a certain degree of bifidity. The

[1] In one specimen in my possession an inferior canine occurs with a bifid fang.

fangs of the lower molars may curve a little backwards; and it is important in dentistry to note that they are directed downwards and outwards, and that therefore a slightly inward inclination should be given to the traction when the forceps is applied to them. In both jaws the third molars, or wisdom teeth, are smaller than the others and may have the fangs dwarfed, the root coming to a single point. In the upper jaw the third molar occasionally has a fang directed quite inwards.

The temporary or milk teeth are smaller than those which replace them. The incisors differ from permanent incisors in having no grooves on the labial surface, and in the fangs being generally narrower at the base as compared with the breadth of the crown. The milk molars have characters similar to the permanent molars, but their fangs diverge and bend round the crowns of the bicuspids, to some extent grasping them.

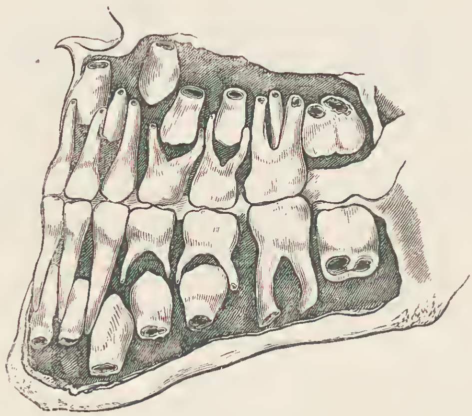


Fig. 530.—Temporary and Permanent Teeth in the jaws of a child six years old. The temporary teeth are all still present, and the crowns of the corresponding permanent teeth are formed; the first molars have appeared, and behind them are the second molars with the divisions between the fangs in process of formation.

Development of the teeth. A tooth, like a hair, is developed in connection with a single papilla which appears in a previously developed recess filled with epithelium. The enamel is, however, the only part developed from epithelium, and even the enamel is derived altogether from the elongated or deepest stratum of corpuscles, while the other layers ultimately disappear. The existence in both jaws of a furrow with ten recesses for the milk teeth was detected at the ninth week of foetal life by F. Arnold (1831), and the details connected with these and with the first appearance of the permanent teeth in the human subject, so far as can be seen with the simple lens on removal of the epithelium, was worked out by Goodsir (1839). His researches show that in the seventh week the primitive groove filled with thickened epithelium appears, and from the bottom of this the series of recesses or *follicles* of the milk teeth, each containing a papilla, is formed, the follicle for the first milk molar appearing first, then that for the second milk molar, next that for the canine, and

lastly those for the incisors, the first incisor before the second. Goodsir demonstrated that the sacs so formed become closed by folds or *opercula* meeting over them, the incisor sacs by two, the canines by three, and the molars by four; also that above these the lips of the groove adhere, the outer lip overlapping the inner; and that between the inner lip and the adjacent operculum another follicle, the *cavity of reserve*, dips in to form the sac of the permanent tooth, and rapidly descends so as to lie deeper than the milk sac, while it continues to be connected with the surface from which it sprang by a cord which passes through the foramen always present on the deep side of the alveolus of the temporary tooth. The sacs of the true molars he showed to be separated in succession backwards from a *posterior* or *great cavity of reserve* continued back from the primitive groove. Later writers, who have observed in section the epithelium filling the various recesses, speak of the epithelium in the groove as the *common enamel-germ*, and of the process descending to the cavity of reserve as the

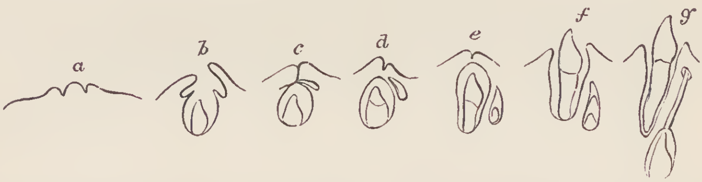


FIG. 531.—DEVELOPMENT OF A TEMPORARY AND A PERMANENT TOOTH. *a*, Papilla in primitive groove; *b*, follicle with opercula over it in the secondary groove; *c*, follicle converted into closed sac by adhesion of opercula, and permanent tooth sac left above inner operculum; *d*, *e*, *f*, permanent tooth sac descending, and temporary tooth growing up; *g*, permanent tooth sac connected with surface by cord passing through foramen in the deep wall of the temporary socket.

secondary enamel-germ, while for the mass inclosed in each sac and for its deepest or columnar layer the terms *enamel-organ* and *enamel-membrane* (Purkinje) are retained. The enamel-membrane is the only part concerned in producing the enamel-prisms; the corpuscles in the middle of the enamel-organ become drawn asunder by fluid, while retaining connection one with another by long and slender branches, and ultimately disappear. Beneath the enamel-membrane a delicate structureless layer appears to exist, for which the old term *preformative membrane* is used. More deeply placed is the layer of odontoblasts, easily distinguished from the corpuscles of the enamel-membrane by their larger size. As the enamel-corpuscles elongate to form prisms, their nuclei remain at the extremity furthest from the dentine.

The enamel and dentine appear simultaneously at the tips of the cusps, each cusp in the multicuspid teeth forming at first a distinct toothlet. The separate cusps unite, and the crowns are completed from above downwards. The roots extend by continuation of growth beyond the sac. In the molar teeth bridges of dentine are formed below the crown by processes growing in to meet one another between separate bundles of vessels and nerves, and the fangs increase in length by growth downwards round those bundles

or divisions of the pulp. It is the increasing length of the root and the resistance offered to it by the neighbouring bone which forces the crown out through the gum. Increase of length of the body of the lower jaw being effected by absorption of the front of the ramus and addition to it behind, the true molars, which at first lie further back than the anterior border of the ramus, find room in front of it before coming to the surface; but the difficulty mentioned at p. 36, in the way of accounting for the growth of either jaw without expansion of osseous tissue already laid down, is illustrated by the position of the permanent canines in Fig. 530.

The eruption of the teeth, both temporary and permanent, occurs generally in very regular order, though in individuals the exact periods vary. The teeth of the lower jaw appear usually a little later than the corresponding teeth of the upper. Of the milk set, the first incisors are the earliest, and appear from the sixth to the ninth month. They are followed by the second incisors, and these by the first molars; then come the canines, and, lastly, about two years of age, the second molars. The milk teeth are shed in consequence of absorption of their fangs, caused by pressure of the permanent teeth; the first and second incisors and first and second molars being displaced respectively about the seventh, eighth, ninth and tenth years of age, and the canines about the eleventh. The first permanent molar appears before the shedding of any of the milk teeth, and the second soon after they have all been shed, while the third molar gets the name of wisdom tooth, on account of the lateness of its appearance, because it does not cut the gum till the seventeenth year or a much later period.

As an *abnormality*, additional incisors or canines, one or more, may appear. They are formed on the lingual side of the permanent teeth, and may cut the gum and give trouble, pushing the normal teeth outside the range, or themselves projecting inside the arch. They may fail ever to come to the surface, or may appear after absorption of alveolar processes. They illustrate that the permanent teeth are each merely the second in a transverse series which may be carried further, as it normally is in many fishes. This circumstance has not received due attention, and was, I believe, noted for the first time in a communication of mine to the British Association in 1893; but both a longitudinal and a transverse series must be recognised in dentition, and this not only affords the true key to explain Goodsir's cavities of reserve, but unifies the scheme of dentition in different animals.

THE MOUTH.

The cavity of the mouth extends back to the pharynx. In front of the ramus of the lower jaw it is divided into a part inclosing the dental arches and a part within them. The mucous membrane is reflected from the lips and cheeks on to the outer surface of both jaws, embraces the teeth, forming around them the gums, and thence is continued on the upper jaw to cover the palate, while, inside the lower jaw, it descends considerably

before being folded round on the under surface of the tongue. But, behind the teeth, internal to the ramus of the jaw, the floor of the mouth suddenly rises almost to a level with the dorsum of the tongue, and, internal to the hindermost tooth of the upper jaw, the hard palate is continued into the *velum palati* or soft palate. The comparatively constricted passage thus bounded above and below, leading into the pharynx, is termed the *fauces*, and has the pendent *uvula* above, and on each side two prominent folds, the *anterior* and *posterior pillars*, separated by the *tonsil*, and corresponding respectively with the positions of the palato-glossus and palato-pharyngeus muscle. At the margin of the lips a sudden change takes place in the integuments. Both sebaceous and sudoriparous glands suddenly disappear, while the papillae become longer and more closely set as far as the lips come in contact, and then diminish. Papillae, however, are found everywhere on the mucous membrane of the oral cavity, and the epithelium remains stratified squamous.

Inside the cheek a slight elevation opposite the second molar tooth of the upper jaw marks the opening of the duct of the parotid gland (Stenson's duct). On the inner surface of each lip there is a slightly prominent fold or *fraenum* made by the mucous membrane in the middle line as it turns round on the jaw.

The labio-buccal mucous membrane rests on loose areolar tissue, and shows on its deep side a number of small glands like lentils which open on its surface. These glands, termed *labial*, *buccal* and *molar*, are situated abundantly inside both lips, and are continued in a line from the angle of the mouth back to the neighbourhood of Stenson's duct, where they may be more abundant. In structure they are acinated. Their acini are flask-shaped with a strong membrana propria, and with an elastic fibrous coat wrapped round the lobules. They are lined with small nucleated corpuscles, and are filled with masses of muciparous substance unstainable with carmine.

FIG. 532.—LABIAL GLANDS exhibited by removal of mucous membrane from inside the lips. 1, Oral aperture; 2, 3, upper and lower lip; 4, cut edge of mucous membrane; 5, a gland; 6, 6, facial arteries; 7, 8, superior and inferior coronary arteries; 9, orbicularis oris; 10, buccinator; 11, depressor anguli oris; 12, levator anguli oris; 13, nerve to lower lip from inferior dental; 14, nerve to upper lip from infraorbital. (Luschka.)

The mucous membrane of the gums and palate differs from that of the cheeks and lips, in being immovable. It is everywhere distinct from the periosteum, and on the hard palate is even separated from it by a considerable thickness of tissue, but white fibrous bands keep it in position. The papillae in the middle of the palate are very short, but they are longer on the gums, especially at the dental margins. The palate presents

two or three transverse *rugae* in its fore part, representative of those so much more obvious in many mammals; also, it has a slight raphe in the middle line, and in front of the raphe, in a portion corresponding with the incisor foramen, there is a slight elevation, with sometimes a depression behind it, a vestige of the mode of development, and representing the orifices which in a number of animals lead up to the floor of the nose opposite the organ of Jacobson. The palate has a large number of acinated glands similar in appearance to those of the lips and cheeks. They are crowded in the soft palate, and are continued forwards into the middle of the hard palate in two patches, one on each side. They have a watery secretion. In the floor of the mouth and on the under surface of the tongue the mucous membrane is more movable than on the cheeks. It presents in the middle line a prominent bridle, *fraenum linguae*, toward whose lower end there is a thickening in which are placed, side by side, the openings of the ducts of the submaxillary glands (Wharton's ducts). On each side, in the hollow between jaw and tongue, there can always be recognised during life a slight elevation produced by the sublingual glands, sometimes presenting a fringe-like line in which lie openings of sublingual ducts (ducts of Walther). There also extends forwards under the tongue, on each side of the fraenum, a little out from it, a scalloped fold, *plica fimbriata*, directed outwards, which has a certain importance as constituting with its fellow the representative of the *under tongue* found in various animals, especially lemurs and marsupials (Gegenbaur).

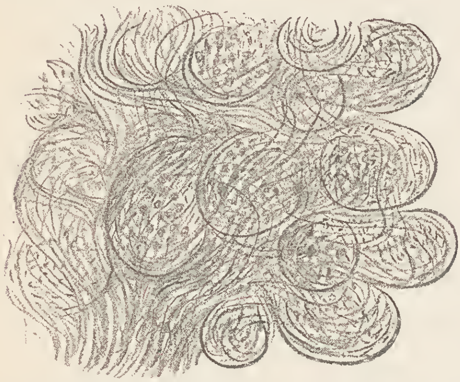


FIG. 533.—ACINI OF LABIAL GLAND treated with sulphuric acid to show the elastic covering.

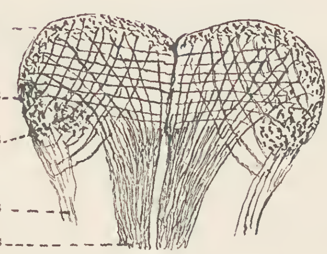


FIG. 534.—DIAGRAM OF TRANSVERSE SECTION OF TONGUE. The transverse and vertical fibres are seen in addition to the named muscles.

The tongue is a muscular structure with a mesial fibrous septum extending forwards from the hyoid bone, and with a specialized form

of mucous membrane on its upper surface. It may be said to be based on the two genio-glossi muscles, already described, whose insertions extend from the tip to the hyoid bone and from the middle line to the lateral margins, so that their fibres are much spread. The other extrinsic muscles, namely, the hyo-glossi, the stylo-glossi, and the palato-glossi take less part in the formation of the tongue, and their fibres do not become so scattered, but along with the linguales muscles and the bodies of the genio-glossi, make a firmer or cortical layer surrounding the main substance of the tongue.

Fig. 535.—The Fauces with the Tongue Protruded, showing the lingual aspect of the epiglottis and the V line behind the circumvallate papillae.

The *intrinsic muscles* are sets of fibres altogether belonging to the tongue, and take longitudinal, transverse and vertical directions. The longitudinal fibres form two pairs of muscles, named superior and inferior linguales. The *lingualis superior* lies underneath the whole upper surface, and consists of fibres of much shorter length attached to the mucous membrane. The *lingualis inferior* lies beneath the outermost fibres of the genio-glossus, where they are curved outwards, and internal to the insertion of the hyo-glossus muscle. The *transverse* and *vertical* fibres are nowhere collected into distinct muscles, but are diffused throughout their extent between the others; the transverse fibres extending outwards from the

mesial septum, the lowermost with a downward and the uppermost with an upward curve; and the vertical fibres stretching between the upper and under surfaces, in curves with the convexity inwards.

The dorsum of the tongue presents a different appearance from the rest of the mucous membrane of the mouth. It is marked in the middle line by a more or less distinct furrow or *raphe* which terminates behind, between the anterior pillars of the fauces, in a blind depression, *foramen caecum*, in the centre of a V-shaped furrow separating a posterior area from the rest of the tongue.[1] In front of this, it is covered with papillae much larger than those of the rest of the mouth or of the skin, and bearing on their surface others corresponding to those. *The papillae* are of three kinds—filiform, fungiform and circumvallate. The *filiform* papillae are set closely all over the surface, with a certain amount of regularity, giving an appearance of lines diverging with forward inclination from the raphe, and ending in distinct ridges at the sides of the tongue, the hindermost of which are best marked, constituting what is sometimes termed *fimbria linguae*, and correspond with more differentiated structures in the rabbit called the *foliate* papillae; their secondary papillae are collected at their tips. The *fungiform* papillae, larger and rounder, are scattered singly at irregular intervals broadcast among the filiform; their secondary papillae are short and abundant, so as to combine superior vascularity and less abundant epithelium, which sometimes suffice to produce a distinctive red colour. The *circumvallate* papillae are larger than the fungiform, about eight or ten in number, ranged in single line in front of the V-shaped furrow. They are somewhat flattened on the summit, and covered with secondary papillae; but their sides, which are sunk in a circular depression, are devoid of these, and are studded with peculiar sense-organs called taste-buds. Behind the V-shaped furrow there is a distance of about an inch in which the convexity of the tongue is continued back towards the epiglottis, and a mesial fold, *fraenum epiglottidis*, joins it to the dorsum of that structure, while a shallow depression is left at each side. In this region the characteristic lingual papillae are absent, though irregular rugae extend back for some distance behind the V-shaped furrow; and the surface presents a number of little openings which are mouths of crypts with closed follicles in their walls, similar to those of the tonsils.

The nerves of the mucous membrane of the tongue are the glossopharyngeal, distributed principally to the region of the circumvallate papillae, and the lingual branch of the fifth, extending to the whole surface. The secondary papillae contain in many instances end-bulbs and sometimes touch-corpuscles.

The taste-buds are organs of sense discovered independently by Lovén

[1] It is to be noted that this relic of the *ductus thyreoglossus* (p. 99) was suspected by Vater to be the duct of the thyroid, and that after many dissections he succeeded, in a child of nine months, in injecting through it what he described and figured as a salivary gland extending under the tongue and round the larynx (1720).

and Schwalbe (1867), easily studied in the foliate papillae of the rabbit and in other mammals. They were at first supposed to be confined in the human subject to the sides of the circumvallate papillae, but have since been found not only in the opposed surfaces of the valla surrounding these, but also scattered on the tongue, especially in the fimbria, and on the

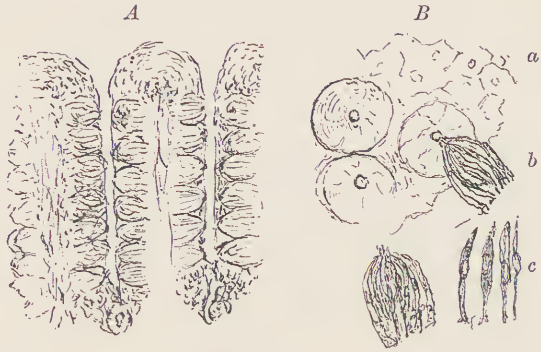


FIG. 536.—TASTE-BUDS from foliate papillae of rabbit. *A*, Papillae with taste-buds on their sides; *B*, separated structures; *a*, under surface of horny epithelium with three perforated hemispherical impressions corresponding with summits of taste-buds; *b*, *b*, isolated taste-buds; *c*, form of nucleated corpuscle found in taste-buds.

under surface of the velum palati and on the epiglottis. They are pointed domes occupying the whole depth of the epidermis. They are composed of elongated nucleated corpuscles with their bases on the corium, and therefore to be considered as modifications of the deepest or perpendicular

FIG. 537.—SECTION OF AN INJECTED TONSIL. *a*, *a*, Mucous membrane of fauces; *b*, a recess; *c*, *c*, *c*, closed follicles.

corpuscles of the cuticle; and their tips occupy openings left in the superficial scaly layers. The circumferent or cortical corpuscles are flattened like staves of a barrel, but pointed at the ends; the central corpuscles are narrow and rounded, with a swelling in the middle caused by the nucleus, a short wire-like extremity projecting at the tip, and with the deep extremity prolonged into continuity with a nerve-fibre.

The glands of the tongue are small acinated glands embedded in the muscular substance. Two minute groups, known as glands of Nuhn or glands of Blandin, are placed on the inner margins of the inferior lingual muscles close to the tip. Others open into the circular depressions round the circumvallate papillae, others into the crypts at the back of the tongue, and others on the margins. Also a row of openings, not usually noticed, lies in the recess concealed by the plica fimbriata. The secreting cells of these glands are many of them of the serous type.

The tonsils (*amygdalae*) are spongy developments of the mucous membrane, which are situated on the sides of the fauces between their anterior and posterior pillars. They are slightly convex on the surface and present a number of irregular orifices leading into crypts simple and branched, and are about a quarter of an inch in thickness. Their thickness and prominence is principally due to closed follicles (p. 68) which are ranged all round the crypts and are embedded in retiform tissue. They rest on fibres of the superior constrictors of the pharynx which lie between them and the internal carotid arteries.

THE SALIVARY GLANDS.

There are three pairs of glands distinguished as salivary which all secrete alkaline saliva containing ptyaline and contrasting with the acid mucus of the labial glands. They are all of them acinated glands, the secreting cells presenting in certain cases the appearance termed serous, and in others that which is distinguished as mucous (p. 58); and beneath the secreting cells so distinguished are others spread out on the basement membrane and pushing in between them, the *lunules* or *crescents of Gianuzzi.* The ducts have vertically striated columnar epithelium, excepting close to the acini, where there is an *intercalary* portion with flattened epithelium.

The parotid gland. This is the largest of the salivary glands. It occupies the space below the ear between the sterno-mastoid muscle and the ramus of the jaw, and extends forwards over the back part of the masseter muscle. Superiorly, it dips deeply in, both in front and behind the styloid process, filling up the interval between the jaw in front and the mastoid process and sterno-mastoid muscle behind. Inferiorly, it extends as low as the angle of the jaw, resting on the stylo-maxillary ligament or fascia, which separates it from the position of the submaxillary gland so effectually that, however much both glands may be swollen, they always remain quite distinct. Embedded in the parotid are the external carotid artery and origins of posterior auricular, superficial temporal and internal maxillary; also, more superficially, the junction of the temporal and internal maxillary veins; and piercing the gland from the posterior and deep part so as to emerge in front are the branches of the facial nerve, while others from the great auricular nerve enter from below and are connected with them. The duct, called usually Stenson's duct (ductus Stenonis), emerges from the anterior border of the gland at

the level of the upper teeth, and crosses the masseter immediately below the transverse facial artery to pierce the buccinator muscle and open into the mouth opposite the second molar of the upper jaw. It is large enough to admit a crow-quill, but is constricted at its orifice. At the origin of the duct the gland is prolonged on the upper border and sometimes presents a distinct lobe opening separately into it, the *pars socia parotidis.* The lobulation of the parotid gland is finer than that of the other salivary glands, and the lobules less easily dissected out from the tissue around. The membrana propria of the acini is delicate. The secreting corpuscles belong to the so-called serous group, being easily stained with carmine, and having spherical nuclei. The place of opening of the duct shows the parotid to be premandibular, the gland having been developed by ramification of the duct, while the submaxillary and sublingual glands are postmandibular.

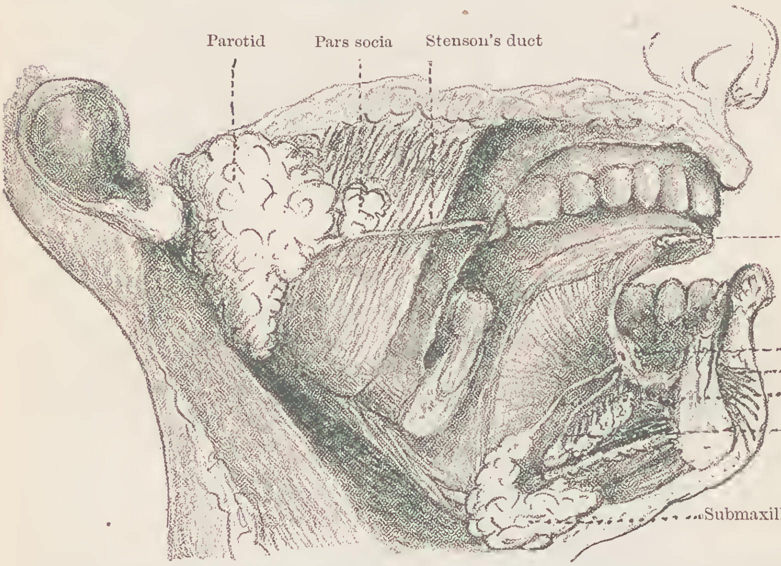


FIG. 538.—SALIVARY GLANDS. A portion of the lower jaw is removed. The mylo-hyoid muscle is seen in section, with the submaxillary gland embracing its free border, and the sublingual gland with Walther's ducts lying above it.

The submaxillary gland is placed in the digastric space, between the base of the jaw and the digastric muscle. Its larger part is superficial to the mylo-hyoid muscle, and is of somewhat circular figure, more than an inch in diameter; but posteriorly it curves round the border of the mylo-hyoid muscle, and from this deep part, which lies beneath the mucous membrane of the mouth, the duct, generally known as *Wharton's duct,* is given off and passes forwards to open near the root of the fraenum linguae by a constricted orifice, on a papilla common to the two ducts of opposite sides. The facial artery crosses the gland near the back, more or less deeply embedded in it and furnishing branches to it. The lingual branch

of the inferior maxillary nerve, descending on the inner side of the jaw, passes under Wharton's duct before ascending to the side of the tongue; and descending from the nerve as it approaches the duct are its branches to the submaxillary ganglion which lies above the duct, near its origin. The

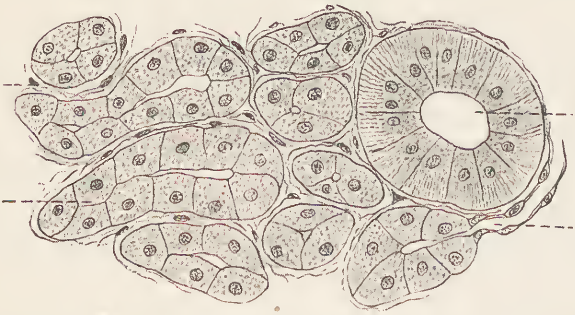


FIG. 539.—SECTION OF PAROTID GLAND, human. (Böhm and v. Davidoff.)

submaxillary gland lies loose in the surrounding textures. Its acini have a stronger membrana propria than the parotid, and in connection with this there is a network of stellate corpuscles. The acini are some of them filled with corpuscles of the muciparous and unstainable kind, and some of them with stainable or serous corpuscles like those of the parotid.

FIG. 540.—SECTION OF SUBMAXILLARY GLAND, human. (Böhm and v. Davidoff.)

The sublingual gland, much the smallest of the salivary glands, is about an inch long and is narrow, lying under the mucous membrane of the floor of the mouth. It rests on the mylo-hyoid muscle, at the side of the genio-glossus and duct of Wharton. It consists of a number of separable lobules, some of which may open into Wharton's duct; but the majority of them, ten to twenty in number, open separately in a line (ducts of Walther); while a larger outermost lobule has a separate duct running along to open near the orifice of Wharton's duct, and was described both

by Rivini and Bartholin before the separate ducts were discovered. The acini are mostly of the muciparous kind and large; but my sections in the human subject show patches of the serous kind, deeply stainable and small.

THE PHARYNX.

The pharynx is that part of the throat which lies behind the posterior nares, the fauces and the larynx. It is distinguished from the oesophagus by its proper muscular wall being deficient in front and consisting of three constrictors already described (p. 345). It is wide above, and extends from the base of the skull to the level of the lower border of the cricoid cartilage, where the lower border of the inferior constrictor grasps the longitudinal muscular fibres of the oesophagus. It has seven openings, four of them above the soft palate, namely, the posterior nares and, at the sides of these, the orifices of the Eustachian tubes; while, beneath the level of the palate, it communicates with the fauces, the larynx and the oesophagus. The upper border of each superior constrictor forms a curved line, and above this the wall of the pharynx is completed by strong fibrous membrane, which is attached to the prominent margin bounding the front of the depressed line near the back of the body of the sphenoid bone and to the edge of the internal pterygoid plate and the cartilaginous wall of the Eustachian tube. In the middle line a ligamentous band of fibres descends from the tubercle underneath the basilar process of the occipital bone to the raphe between the constrictors.

The mucous membrane of the pharynx, where it quits the fibrous wall to be reflected on the base of the skull, is thrown into irregular ridges and hollows, and on each side forms a blind pouch, the *pharyngeal recess* or *fossa of Rosenmüller*, above and behind the cartilaginous wall of the Eustachian tube, so that the cartilage lies between the recess and the tube. On the back and sides of the suprapalatal part of the pharynx patches of closed follicles are seen. The epithelium above the level of the palate is ciliated columnar, as in the lower part of the nasal fossae; while below the palate it is squamous stratified, as in the fauces and oral cavity.

THE OESOPHAGUS.

The oesophagus or gullet, extending from the pharynx to the stomach, commences opposite the lower border of the cricoid cartilage and of the fifth cervical vertebra, and terminates after piercing the diaphragm opposite the tenth dorsal vertebra. It is nine or ten inches long, and is the most muscular and constricted part of the alimentary tube. It is slightly narrower at its commencement and near its termination than elsewhere. Though nearly straight, it deviates slightly to the left side at its commencement, regaining the mesial position about the level of the fifth dorsal vertebra, and is again inclined to the left where it pierces the diaphragm.

Resting in the neck and upper part of the thorax on the longus colli and bodies of vertebrae, as it descends further it is bent forwards and removed from contact with the vertebral column by the intervention of the aorta which, placed to the left at the commencement of its descent, is mesial in position where it passes between the crura of the diaphragm. In front are the trachea and commencement of the left bronchus and, below this, the pericardium. The left common carotid artery is more closely in contact with the oesophagus than the right, partly because it arises nearer the vertebral column and partly on account of the deviation of the oesophagus to the left side. The recurrent laryngeal nerves lie close in between the oesophagus and sides of the trachea. The vagus nerves come into close contact with the oesophagus below the arch of the aorta, and as they descend, giving branches to its walls, the right nerve turns to the posterior and the left to the anterior surface. The thoracic duct lies between the oesophagus and right vena azygos in the lower part of the thorax, and between oesophagus and vertebral column higher up.

The walls of the oesophagus present three coats—muscular, submucous and mucous.

The *muscular* coat has its fibres evenly disposed in two layers, longitudinal and circular. The longitudinal fibres are most superficial, and at the upper part take origin from the cricoid cartilage anteriorly, and from the inner surface of the inferior constrictor of the pharynx behind and at the sides. The circular fibres are surrounded by the longitudinal, and above are separated by them from the constrictors of the pharynx.

The *submucous* coat consists of loose areolar tissue which allows the mucous coat to fall into longitudinal folds within the grasp of the muscular coat.

The *mucous membrane* presents, besides epithelium, two layers which can be stripped separate one from the other. That which is next to the submucous areolar tissue consists of longitudinal fibres, which inferiorly are muscular (Toldt) and continuous with the muscularis mucosae of the stomach. The other, the mucous membrane proper, is a firm felted tissue, and on the surface presents loosely scattered papillae, some isolated and some connected in rows, which when denuded of epithelium are filiform. The epithelium is stratified squamous, like the lower part of the pharynx, and forms tubercular elevations over the papillae.

Small *mucous glands* are sparsely scattered in the upper part of the oesophagus, in the submucous layer.

THE STOMACH.

The oesophagus, after piercing the diaphragm, opens into the stomach, the first abdominal portion of the digestive tract, and separated from the intestine by a valve termed the *pylorus*, which consists of a ring of additional fibres of the inner muscular coat and a circular fold of mucous

membrane constricting the diameter of the aperture of communication to about half an inch when at rest. The oesophageal or *cardiac* orifice is opposite the tenth thoracic vertebra, a little to the left of the mesial plane, while the pylorus is about two inches lower, and a little to the right of the mesial plane, beneath the left end of the portal fissure of the liver, with which it is connected by means of the gastro-hepatic omentum.

The stomach presents an anterior and a posterior surface, which are applied one to the other when it is empty, and are limited by two borders. The upper border or *smaller curvature,* short and concave, descends from the right side of the cardiac orifice and crosses the middle line to reach the pylorus; to it the gastro-hepatic omentum and gastro-phrenic ligament are attached.

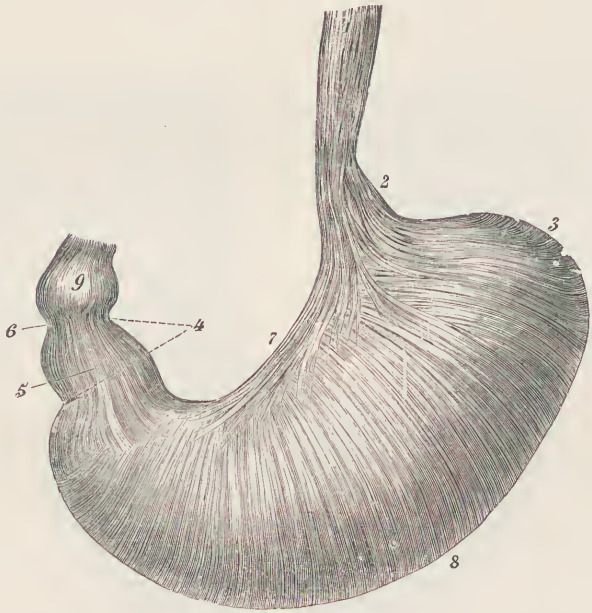


FIG. 541.—STOMACH SHOWING SUPERFICIAL MUSCULAR FIBRES. 1, Oesophagus; 2, carotid; 3, cul-de-sac; 4, pyloric antrum; 5, anterior pyloric ligament of Helvetius; 6, pylorus; 7, 8, smaller and greater curvature; 9, duodenum. (Luschka.)

The other border, the *great curvature,* is much larger and sweeps to the left from the cardiac orifice, then turns round below, and as it nears the pylorus, gradually approaches to the upper border; to it is attached the pendulous gastro-colic omentum. When the stomach is empty and contracted it descends for about two-thirds of its extent before curving to the right. In the distended condition the surfaces are rounded out; the greatest vertical antero-posterior section is opposite the cardiac orifice, the part properly termed the *fundus*; to the left of this there is a large hemispherical recess, the *great cul-de-sac,* sometimes, but improperly, called fundus; while to the right the diameter gradually diminishes. Near the pylorus the curve is completed, and a slight bend in the opposite direction distinguishes the *antrum of the pylorus.*

When distended the stomach fills the greater part of the left hypochondrium, the epigastrium below the liver, and part of the right hypochondrium ; and it may reach to as much as a foot in length, and five inches in width. In this state, also, it is changed in position in two respects: it is rotated so as to throw the inferior border forwards, in consequence of enlargement backwards being impossible, and it is thrown into a transverse position by the levels of the orifices remaining the same while the dimensions of the organ are increased. The nervous supply is from the pneumogastrics and the sympathetic. The left pneumogastric descends from the oesophagus on the front, and the right on the back of the stomach. The sympathetic branches accompany the arteries. Minute ganglia (*of Remak*) are scattered in the walls.

The walls of the stomach present four coats, namely, the serous, muscular, submucous and mucous.

The serous or *peritoneal coat* is derived in front from the general peritoneum, and behind from the smaller sac, and is complete except along the lines of the great and small curvatures.

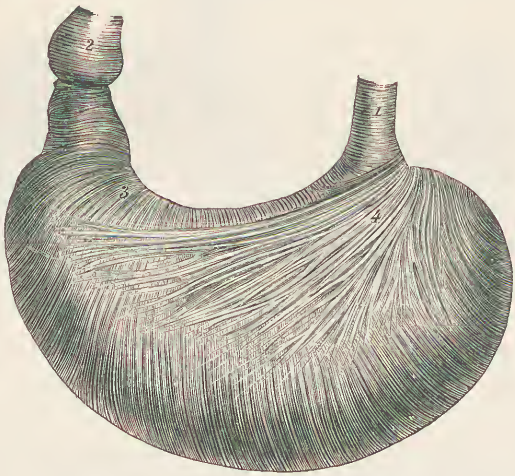


FIG. 542.—STOMACH EVERTED to show muscles seen on removal of mucous membrane. 1, Oesophagus ; 2, duodenum ; 3, circular fibres ; 4, oblique fibres. (Luschka.)

The muscular coat presents three different sets of fibres. The outermost are *longitudinal*, continuous with the longitudinal fibres of the oesophagus, and are most abundant along the two curvatures. The intermediate layer is the most complete, and consists of *circular* fibres, which on the cardiac cul-de-sac are comparatively thin, but are interesting in respect that they form rings altogether to the left of the oesophageal orifice, and thus demonstrate it to be no mere expansion, but a caecal outgrowth such as is found more distinctly in many other mammals. The circular fibres become more abundant as the pylorus is approached, and take part in the formation of the valve by means of a specially developed thick ring. The innermost

set of muscular fibres is the least perfect layer, and, like the circular fibres, it is continuous with the circular layer of the oesophagus. Its fibres are *oblique*, and form arches to the left of the oesophagus, which spread obliquely downwards and to the right on the front and back, the uppermost fibres being the strongest and running nearly parallel to the smaller curvature. They have been described as a *cravate de suisse*, and leave uncovered between the cardiac and pyloric orifices a tract which by their contraction might be separated by a constriction from the rest of the cavity and serve to conduct fluids directly to the intestine (Larger).

The submucous coat consists of loose areolar tissue. In it the arteries for the mucous membrane break up into small branches, and the emerging veins are gathered into larger vessels, and it allows the mucous membrane to be thrown into folds when the muscular coat is contracted.

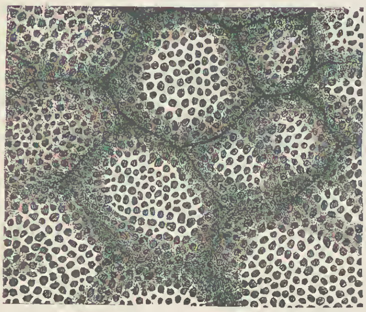


FIG. 543.—GASTRIC MUCOUS MEMBRANE, $\frac{15}{1}$, hardened in chromic acid, showing the mamillated condition, and over the mamillae the depressions into which the follicles open. (Luschka.)

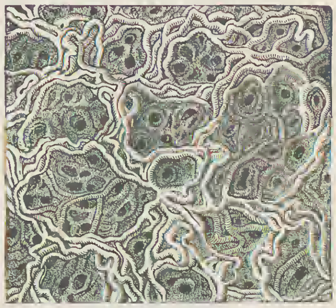


FIG. 544.—OPAQUE INJECTION OF MUCOUS MEMBRANE OF STOMACH, $\frac{70}{1}$, showing, besides the bloodvessels, the shallow depressions into which the gastric follicles open. (Luschka.)

The mucous membrane is smooth, soft, lustreless, spongy and thick compared with that of the intestine, and without thread-like or villous projections on its surface. It differs both in thickness and in superficial appearance in different conditions of engorgement. The thickness may reach to as much as a twelfth of an inch in the fundus, but probably is never more than half so great near the pylorus, and it is still less in the great cul-de-sac. The largest inequalities of surface are the *rugae*, a set of irregular temporary elevations caused by folding of the whole thickness of the mucous membrane in consequence of contraction of the muscular coat; the more prominent rugae follow a longitudinal direction. The surface in the least swollen condition of the mucous membrane is uniform, but in other instances or other parts it is mamillated, exhibiting minute curving elevations separated by shallow linear depressions, which, when the swelling is still greater, are converted into larger dimples separated by prominent ridges. A more minute inequality of surface can be brought into view under low powers of the microscope, namely, a series of shallow depressions into which the gastric follicles open in groups of from four to twelve. Formerly they

were described in an exaggerated manner, which has led to their being latterly overlooked almost altogether.

The mucous membrane is bounded on its deep side by a thin but firm layer of decussating muscular fibres, *muscularis mucosae.* In the rest of its depth it consists principally of secreting tubes, the gastric follicles. These, save in the neighbourhood of the pylorus and close to the oesophagus, are simple tubules embedded in loose retiform tissue, their somewhat dilated extremities reaching down to the muscularis mucosae, and their necks bound more firmly together. The whole surface of the mucous membrane, and also the necks of the follicles, are lined with columnar epithelium, which takes the place of the stratified squamous when the oesophagus has opened into the stomach. But, beyond their necks, the simple tubular gastric follicles have their secreting cells polyhedral and of very various size, the larger cells more distinctly granular and the smaller interspersed between them in a rather irregular fashion, by no means covering them nor arranged in very definite order.

FIG. 545.—SECTION OF MUCOUS MEMBRANE OF HUMAN STOMACH at its thickest part. *a*, Necks of follicles lined with columnar epithelium; *b*, dilated ends of follicles; *c*, retiform tissue; *d*, muscularis mucosae.

In the dog, the cat, and other animals, the two kinds of corpuscles found in the gastric follicles are more definitely distinguished. One set, the *principal* or, more properly, the *central* cells, is continuous with the columnar epithelium of the necks of the follicles, and consists of small, clear, nearly cubical corpuscles. The other, the *parietal* or *underlying* cells, are large, oval and granular, much less liable to alteration after death, and, in some conditions of the tubules, bulge out hemispherically from their sides; they were at one time named *peptic* from an erroneous idea that they were the sole secretors of pepsin, while the small set secreted mucus. In the dog, towards the pylorus, the glands are more branched, and are destitute of the larger or marginal cells; and numerous experiments have been made to decide the functions of the two orders of cells by working with portions of mucous membrane from the cardiac and pyloric regions.

In the human subject, within the pyloric antrum, the follicles become

shorter and the larger corpuscles more scarce, and close to the valve short tubules are arranged in groups opening into the duct. On the valvular

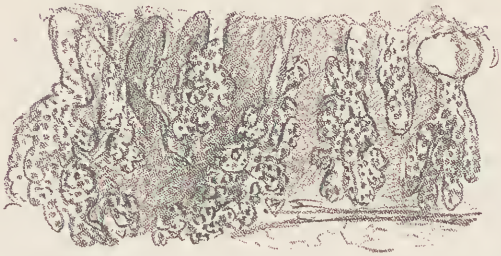


FIG. 546.—MUCOUS MEMBRANE OF STOMACHIC SIDE OF PYLORIC VALVE, showing branched glands. *a*, Muscularis mucosae interrupted by large pyloric glands.

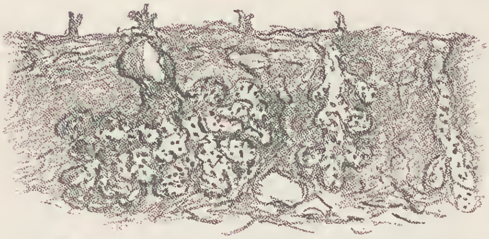


FIG. 547.—MUCOUS MEMBRANE IMMEDIATELY BELOW OESOPHAGEAL OPENING OF STOMACH, showing branching glands, and on the surface thread-like papillae denuded of epithelium, human.

fold itself the branching of tubes is carried much further, and the glands increase in size and burst through the muscularis mucosae which is inter-

FIG. 548.—FROM FUNDUS OF HUMAN STOMACH, $\frac{500}{1}$. (Böhm and v. Davidoff.)

rupted by them; and they present the appearance in section of racemose

glands lined with regular cubical epithelium surrounding a considerable lumen. At the summit of the valvular fold these glands suddenly cease, villi and simple tubules at once begin, and the intestinal muscularis mucosae starts close to the surface. Compound tubular glands containing large cells are found close to the cardiac orifice where the oesophageal epithelium and papillae have not yet disappeared.[1]

Between the glands and towards the surface special collections of minute unwalled corpuscles are here and there scattered in the retiform tissue, sometimes uninclosed, and generally less distinctly bounded than the closed follicles of the intestine. These are the *conglobate* or *lenticular* glands of authors, though other structures may have been sometimes confused with them.

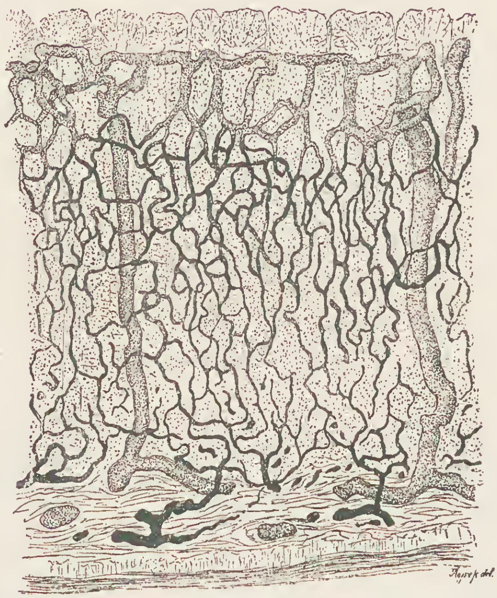


Fig. 549.—Section of Injected Mucous Membrane of Stomach of Cat. Arteries and arterial capillaries, black; veins and venous capillaries, grey. (Toldt.)

The *bloodvessels* of the mucous membrane are arranged in such a manner as to secure the flow of pure blood through its texture. Immediately on

[1] A good deal of work remains to be done on the differences of the mucous membrane of the human stomach in different parts and in different conditions. The operations now sometimes performed may afford means for obtaining fresh material for such research. Meanwhile, the account by Edinger (*Archiv. Micr. Anat.*, 1880) is probably as accurate as any, and I quite agree with the view there suggested, that in the human subject the different sizes of corpuscles are probably different stages of one series. The glands of the pyloric valve have been confused with Brunner's glands, but are quite different both in their relation to the muscularis mucosae and in their contents. The compound glands at the cardiac orifice were noted and figured by Allen Thomson in Goodsir's *Annals*, 1850.

piercing the muscularis mucosae the arteries break up into a network of capillaries for the supply of the glands; and on the surface there is a closer capillary network from which the venous radicles, fewer in number than the arterioles, and larger, descend in straight course, taking at once away from the tissue the impure blood to which have been added substances imbibed from the cavity of the viscus. The lymphatics begin near the surface of the mucous membrane in loops and dilated spaces which fall into a finer network, whence vessels pierce the muscularis mucosae to enter the valved lymphatics of the submucous coat.

THE INTESTINE.

The intestine extends from the pyloric valve to the anus, and is divided into *small* and *great* intestines, separated one from the other by the ileo-colic valve. It presents a more or less complete peritoneal covering, a muscular coat arranged in two layers, of which the outer consists of longitudinal and the inner of circular fibres, and a mucous membrane separated from the muscular coat by a submucous coat of loose connective tissue thinner than that of the stomach.

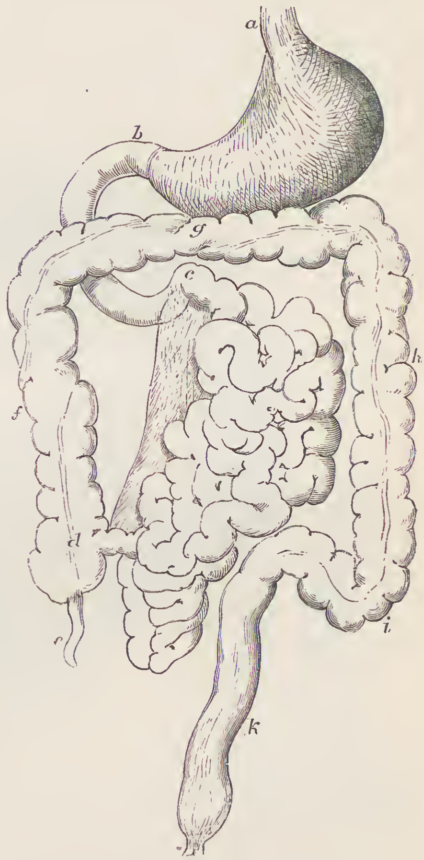


Fig. 550.—Abdominal Part of Digestive Tube. *a*, Oesophageal opening of stomach; *b*, pylorus; *b* to *c*, duodenum; *c* to *d*, jejunum and ileum with line of attachment of mesentery; *d*, above the caecum, below the ascending colon, and opposite the ileo-colic valve; *e*, vermiform appendage; *f*, *g*, *h*, ascending, transverse and descending colon; *i*, sigmoid flexure; *k*, rectum.

The small intestine is counted as about twenty feet in length and is characterized throughout by its regular cylindrical form and the even distribution of both the thin longitudinal and the thicker circular muscular fibres. Its diameter diminishes gradually from the commencement, where it reaches from an inch and a quarter to an inch and a half, as far as its termination, where it is less than an inch. It is divided into duodenum, jejunum and ileum.

The duodenum is that part which is fixed in position and destitute of mesentery. It is about nine or ten inches long, and got its name to

indicate twelve fingerbreadths as its length. It is directed in its first part from the pylorus horizontally toward the right under cover of the liver and gall-bladder, and invested like the stomach with the general peritoneum in front and the smaller sac behind. It then gets beyond the smaller sac and descends in front of the right kidney opposite the second and third lumbar vertebrae, and covered with peritoneum in front only. The remainder or third part turns to the left as far as the middle line, crossing the inferior vena cava, and then proceeds almost vertically upwards in front of the aorta to end abruptly opposite the second lumbar vertebra by being suspended in a constant position from the surface of the left crus of the diaphragm by a long, broad and strong fibrous sheet

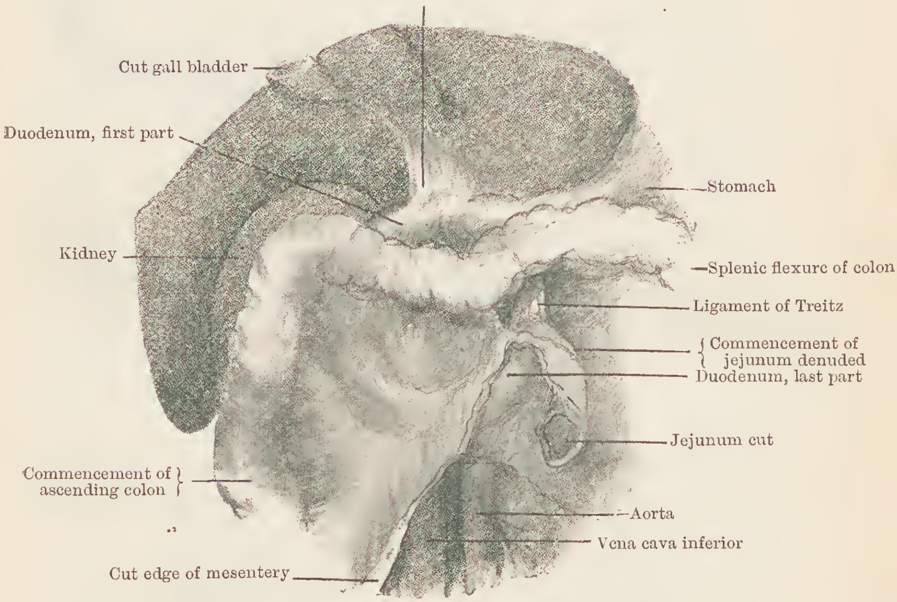


FIG. 551.—RELATIONS OF DUODENUM. (Alexander Macphail, M.B.)

containing muscular fibres, the *ligament of Treitz.* This third part, being crossed first by the transverse mesocolon, and afterwards by the commencement of the mesentery, is only in contact with the peritoneum between these two structures, and in half the breadth of its ascending portion to the left of the mesentery. The common bile-duct and the pancreatic duct or ducts open on the posterior wall of the descending part of the duodenum. The concavity of its curve is occupied by the head of the pancreas, and the arteries which supply it are the superior and inferior pancreatico-duodenal, one a branch of the hepatic artery and the other of the superior mesenteric.

The jejunum and the **ileum** include the whole of that part of the small intestine which is connected by mesentery with the abdominal wall,

namely, from the duodenum to the ileo-colic valve. It is customary to give the name jejunum to the upper two-fifths and to call the other three-fifths ileum, but the only structural differences between the upper and lower parts take place in quite a gradual manner. The distinction to which the jejunum owes its name is its usually more empty condition both as regards solid and gaseous matters. The arrangements for absorption are most developed in the upper part of the intestine, and the muscular activity may be habitually greater, but, whatever may be the cause, it is an easily observed fact that the jejunum is not so habitually distended as the ileum. Both jejunum and ileum receive their blood entirely from the superior mesenteric artery and their nerves from the plexus of the same name.

An occasional *diverticulum* occurs on the ileum, perhaps as often as once in a hundred bodies. These diverticula are short blind protrusions lined with mucous membrane, and presenting regular muscular walls with circular and longitudinal fibres. They are confined to a limited region, usually from eighteen inches to four feet above the ileo-colic valve, and may project at right angles to the intestine or slope in a downward direction. There can be no doubt that their position corresponds with that of the extremity of the loop which projected in connection with the umbilical vesicle in the embryo, as was first recognized by Meckel, though the structure had been often observed before, and had been figured by Ruysch.

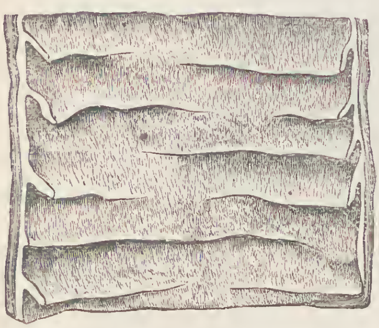


Fig. 552.

Fig. 553.

Fig. 552.—Valvulae Conniventes exhibited in a piece of jejunum cut open, $\frac{2}{1}$.

Fig. 553—Villi, human, denuded of epithelium, lacteals and bloodvessels injected. Lacteals, white; bloodvessels, black. (After Teichmann.)

The mucous membrane presents in a great part of its extent permanent transverse folds of its whole thickness. These are called *valvulae conniventes*, and, where most developed, have a crescentic form, extending two-thirds round the intestine, projecting a quarter of an inch in the middle, and placed about the same distance one from another. No one fold directly overlies the next, but they are placed irregularly so as to be equally distributed round about. They begin about two inches from the pylorus, and

are largest and most frequent in the last part of the duodenum and beginning of the jejunum. They become smaller, and are placed at greater distances apart in the lower part of the jejunum, and dwindle away altogether below the middle of the ileum.

The mucous membrane of the intestine is firmer and thinner than that of the stomach, and has this distinctive character that it is covered with minute processes called villi, which begin at the margin of the pyloric valve and cease at the margin of the ileo-caecal valve, and stand out like velvet-pile when the membrane is placed in water. It consists of closely set secreting tubules, supported by retiform tissue and resting on a thin stratum of muscular fibre, the *muscularis mucosae*.

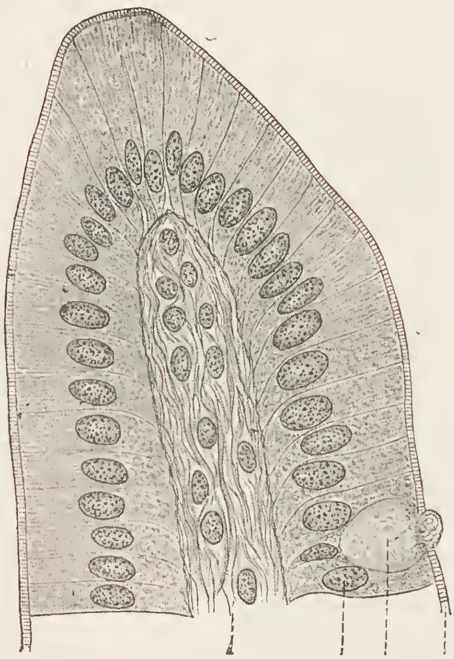


FIG. 554.—SECTION OF TIP OF VILLUS, man, $\frac{900}{1}$. (Böhm and v. Davidoff.)

The epithelium of the surface, both of the villi and the intervals between, is columnar and characterized by a thickening on the free extremities of the cells. This thickening is a pulpy substance continuous over them, less firm than their deep walls, neither swelling nor collapsing so easily as they, and permeable by the oily particles of the chyme, which thus enter the interior of the cells and may load them to the extent of concealing the nucleus; it presents in different conditions more or less distinct vertical striation. Scattered among the other columnar cells are some distended with mucus which displaces the nucleus to the deep end, and others widely open by escape of this mucus and called goblet-cells (p. 58).

The villi are longest in the duodenum and upper part of the jejunum, where they may reach to the thirty-sixth of an inch in length, and are placed exceedingly closely; and they become shorter and sparser till at the lower part of the ileum they are no longer than broad and are scattered distinctly one from another. They are liable to considerable variation in different subjects, being, in the jejunum, sometimes filiform and sometimes flattened and connected. In many animals they are longer, narrower and covered with larger epithelial cells than in man. That the epithelial cells of the villi are actually prolonged into processes in continuity with branched corpuscles more deeply placed may be questioned, although there is high authority for the allegation, but there can be no doubt that the molecular substance which they take in from the chyme is passed on from them into the lymphatic radicles. One or more such radicles run down the centre of each villus and begin as an unwalled space, which may be clavately enlarged; while the bloodvessels are arranged in a single layer at the circumference.

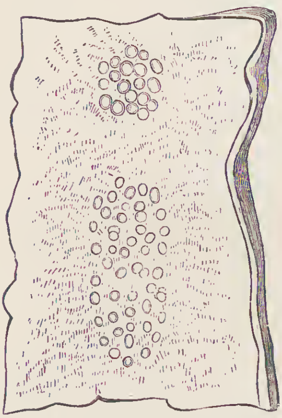


Fig. 555.—Two Peyer's Patches natural size.

Fig. 556.—Section of Duodenum. *a*, Villi; *b*, Lieberkühn's follicles; *c*, a Brünner's gland; *d*, muscular wall.

The glands which take part in the structure of the mucous membrane are the *crypts* or *follicles of Lieberkühn*, simple tubes passing straight from the surface down to the muscularis mucosae, lined throughout with columnar epithelium. But in the duodenum there is a special set of glands called *Brünner's glands* not found in the rest of the intestine. These are small acinated glands, barely visible with the naked eye, lying in numbers in the submucous tissue, immediately underneath the muscularis mucosae, which is pierced by the single duct of each.

Closed follicles or lymphatic nodules, distinguished as *solitary glands*, are scattered in the mucous membrane of the whole small intestine. Others are gathered together in groups, and are termed *agminated glands* or *Peyer's*

patches. These may be said to be peculiar to the ileum, and at first are scattered and small, but increase in size and frequency lower down. They are about half an inch in breadth, and vary from the circular form to a length of more than two inches. The closed follicles have firm walls of connective tissue, and contain minute lymphoid corpuscles and fine threads of connective tissue, with loops of capillary bloodvessels converging to the centre. They slightly project on the surface in the recent state, and reach down into the submucous tissue.

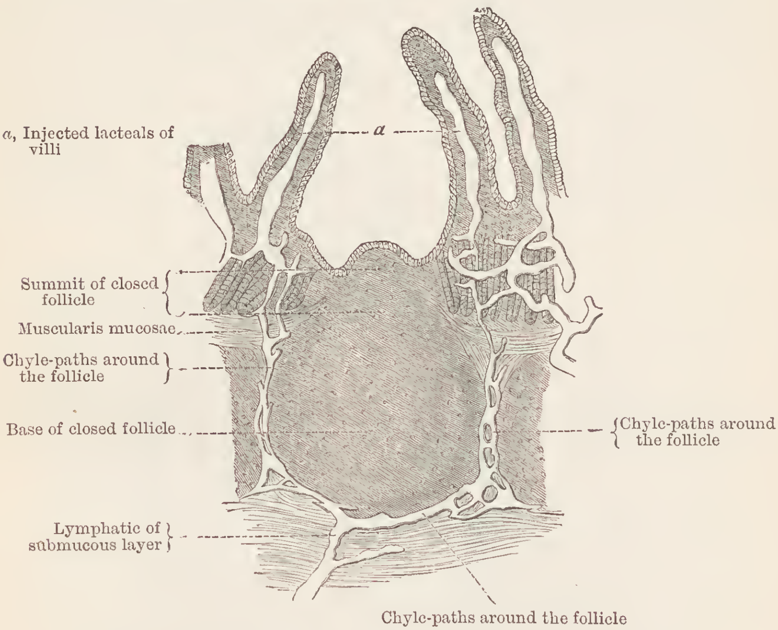


FIG. 557.—CLOSED FOLLICLES, VILLI AND LACTEALS, CAT, $\frac{30}{1}$. (After Frey.)

The bloodvessels of the mucous membrane present the peculiarity seen more distinctly in the stomach that the glands are supplied by capillaries given off from arterioles immediately after piercing the muscularis mucosae, and pour their blood into larger capillaries on the surface where the venous radicles take origin; but the arterioles are continued on to supply the villi, breaking up at the bases of these into large capillaries, which in the broader villi run parallel one to another, united by smaller branches. Each villus has its bloodvessels confined to the surface, so as to form a web in the form of a hollow cone. *The lacteals* arise, as already described, in the interior of the villi, and fall into a network of smaller vessels in the substance of the mucous membrane, which discharges its contents into a network of wider vessels in the submucous coat, immediately beneath the muscularis mucosae. This network specially surrounds the base of each closed follicle, but does not seem to communicate with its interior, and has never been alleged to do so.

The nerves of the small intestine are supplied by the superior mesenteric plexus of the sympathetic, and form in the walls two meshed and gangliated plexuses. One of these, *Auerbach's plexus*, is situated between the longitudinal and circular layers of the muscular coat; the other, *Meissner's plexus*, is in the submucous coat. From the latter, fine branches have been traced forming a netted plexus both in the substance of the mucous membrane and in the villi.

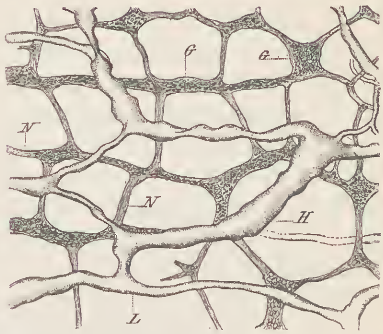


FIG. 558.—INTERMUSCULAR LYMPHATICS AND MYENTERIC PLEXUS OF GUINEA PIG, $\frac{30}{1}$. *L*, Lymphatics; *G*, ganglia; *N*, nerve-cords. (Auerbach.)

The large intestine is about five or six feet long; it may be said in general terms to be about twice the diameter of the small intestine, and, like it, is largest at the commencement, and gradually narrows as far as the rectal dilatation. It begins in a short and wide blind pouch, *the caecum*; the caecum, at the place where the ileum opens into it laterally, is continued into the *colon*; the colon constitutes the greater part of the large intestine, and is divided into ascending, transverse and descending colon and the sigmoid flexure; and the sigmoid flexure falls into the *rectum*. In its whole extent, with the exception of the rectum, the large intestine has a sacculated appearance, contrasting with the even cylindrical form of the small intestine. This sacculation involves the mucous, submucous, muscular and serous coats, but is maintained by the arrangement of the fibres of the muscular coat. The longitudinal muscular fibres are arranged principally in three strong bands or *taeniae*, distinguished as mesenteric, posterior and lateral, and only a few are scattered between the bands. The circular fibres also are more numerous between the saccules than over them. An additional peculiarity

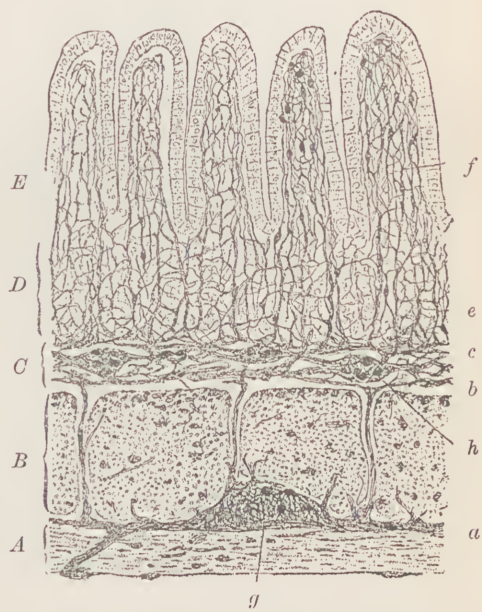


FIG. 559.—SECTION OF SMALL INTESTINE OF GUINEA PIG. *A*, Longitudinal muscular layer; *B*, circular layer; *C*, submucous layer; *D*, Lieberkühn's follicles; *E*, villi; *a*, Auerbach's plexus; *b*, deep myenteric plexus cut across; *c*, Meissner's plexus; *e*, periglandular plexus; *f*, intravillous plexus. (Cajal.)

of appearance is given by little appendages and projections of peritoneum inclosing fat, *appendices epiploicae;* they may be as much as an inch or more in length, and are most numerous near one of the longitudinal bands on the concavity of the arch formed by the colon.

The mucous membrane is destitute of villi, thinner, firmer and more glistening than that of the stomach. It presents, like the small intestine, straight secreting tubules extending down to the muscularis mucosae, and lined with columnar epithelium. The name of *follicles of Lieberkühn* is sometimes extended to them. They are longer and more closely set than those of the small intestine. Closed follicles are scattered singly (*solitary glands*) over the surface. The bloodvessels and lymphatics are arranged as in the stomach.

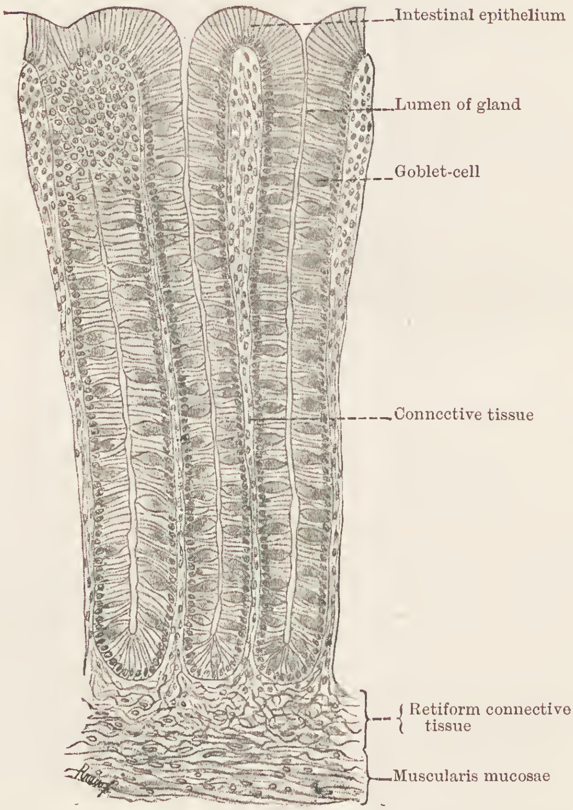


FIG. 560.—MUCOUS MEMBRANE OF COLON, human, $\frac{200}{1}$. (Böhm and v. Davidoff.)

The nerves of the great intestine come from the superior and inferior mesenteric plexuses, and form gangliated networks on the coats, similar to those in the small intestine.

The caecum (*intestinum caecum* or *caput caecum coli*), the blind pouch below the ileo-colic valve, is situated in the right iliac fossa, opposite the

outer half of Poupart's ligament. It is about as deep as it is broad when distended, and similar in appearance to the colon, but represents a portion of the intestine which in some animals is largely developed and quite distinct from the colon. It has coming off from it at the inner side of its lower end a prolongation, the *vermiform appendage*, usually about three inches in length, and sufficiently wide to admit a crow-quill easily. This appendix has considerable pathological importance, being liable to inflammation, and appendicitis often requiring surgical interference; and it may well be doubted if this affection is always determined by mechanical causes, when it is considered that, like the tonsils and Peyer's patches, its mucous membrane is principally devoted to closed follicles. It has also a considerable importance morphologically, for, present in the orang and chimpanzee, it is generally absent in monkeys and in the majority of mammals, yet is present among marsupials, the caecum and vermiform

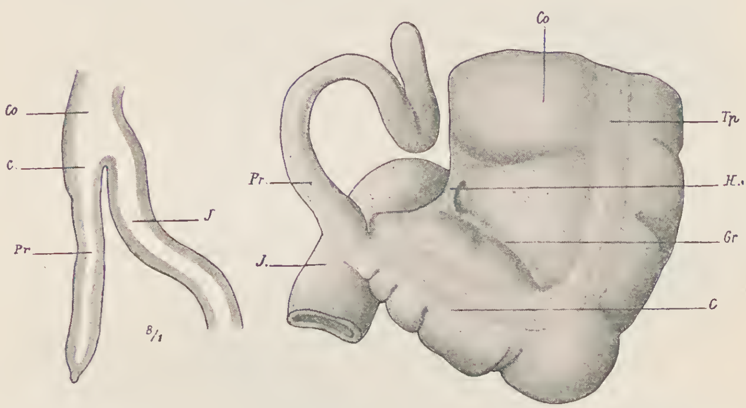


FIG. 561.—DEVELOPMENT OF CAECUM AND VERMIFORM APPENDAGE. *A*, From embryo of eighth week; *B*, from a girl three years old; *C*, caecum; *Co*, colon; *Gr*, boundary-fold; *H*, habenula caeci; *J*, ileum; *Pr*, processus vermiformis; *Tp*, taenia posterior. (Toldt.)

appendage of the wombat having sometimes been compared with those of man; and in certain rodents, as in the rabbit, it is of large dimensions, while in others, as the rat, it is completely absent. The caecum is completely surrounded with peritoneum, and a mesocaecum extends from below the ileo-caecal valve along the vermiform appendage. The vermiform appendage is in point of fact the true starting-point of the taeniae of the colon. The caecum and appendix have their origin so early as in the embryo of six weeks, in the form of a projection taking an upward direction, as do the caeca of monotremata, birds, reptiles and fishes in which caeca occur. The three fraena of the colon together spring from the vermiform appendix, and persist distinct for a variable number of years. The fraenum mesentericum, however, early becomes short as compared with the others, and is concerned in a folding inwards and backwards of the caecum which commences in the embryo of nine weeks. The part of the

fraenum crossing the fold is called the habenula. The importance of this fold in the development of the under lip of the ileo-colic valve has been shown by Toldt, and derives additional interest from the circumstance that the form of the human ileo-colic valve is peculiar, the usual form in mammals being circular, as it is originally in the human foetus. The varieties of peritoneal connection of the caecum and vermiform appendix, and the tendency of the latter to be coiled up and concealed behind the caecum, have recently received great attention at the hands of various anatomists, especially Treves and Huntington.

The *ileo-caecal* or *ileo-colic valve* is an arrangement by which reflux of the contents of the great intestine into the ileum is prevented. It consists of an upper and a lower lip of mucous membrane projecting from the aperture of the ileum into the colon, while the anterior and posterior angles of junction of the two lips are prolonged as projecting folds (fraena) more or less round the colon. The upper lip projects transversely, and the lower obliquely upwards, and the lower is much the broader. Villi and closed follicles, agminated glands, are found on the opposed surfaces of the lips and cease at their edges. Distension of the colon puts the lips on the stretch, and thus keeps them in close apposition.

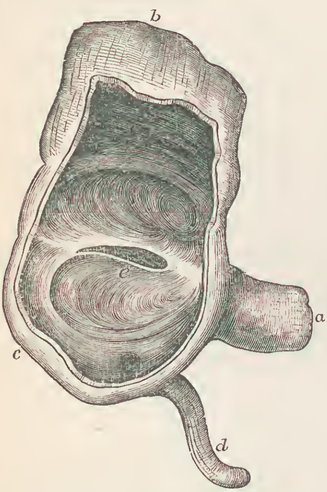


FIG. 562.—THE CAECUM AND ILEO-COLIC VALVE. *a*, Ileum ; *b*, ascending colon : *c*, caecum ; *d*, vermiform appendage.

The colon. The *ascending colon* extends upwards from the caecum, in contact with the posterior wall of the abdomen, being to a certain exent uncovered by peritoneum behind. It passes from the right iliac region, through the right lumbar, and into the right hypochondriac region, where it is continued into the transverse colon by making a sharp turn, the *hepatic flexure*, which rests against a slight depression on the anterior half of the under surface of the right lobe of the liver.

The *transverse colon* at its commencement runs with a forward and downward inclination ; it then crosses in front of the small intestines below the stomach, and inclines upwards and backwards below the spleen to end in the descending colon by taking a sudden turn, the *splenic flexure*, at a higher level and further back than the hepatic flexure. The transverse colon may be said to have a mesocolon in its whole length, but at its commencement the mesocolon is so narrow that the colon is almost in contact with the duodenum where it crosses it ; and it is narrower again at the splenic flexure, where it ends in a prominent (*costo-colic*) fold. But in the intervening part, where the smaller sac of the peritoneum takes part in its formation, the mesocolon is broad, and sometimes it is greatly stretched

and the transverse colon arched downwards so as to approach the brim of the pelvis.

The *descending colon* extends from the splenic flexure in the left hypochondrium, through the left lumbar region, to the upper and back part of the left iliac, and is imperfectly covered with peritoneum, being in contact with the posterior abdominal wall.

The *sigmoid flexure* is a loop continuous with the descending colon, forming in conjunction with the commencement of the rectum the double curve from which it takes its name. The loop hangs loose by a mesocolon, continuous below with the mesorectum.

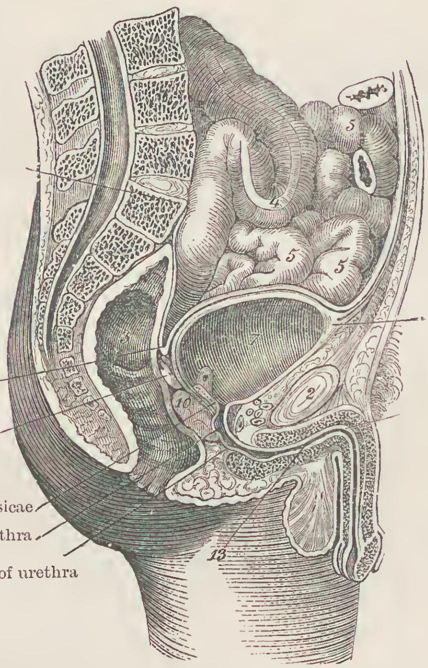


Fig. 563.—Mesial Section of Male Pelvis. 2, Symphysis pubis; 3, rectum; 4, sigmoid flexure; 5, 5, small intestine; 7, urinary bladder; 10, prostate; 13, spongy part of urethra. (Luschka.)

The rectum, about eight inches in length, extends from opposite the left sacro-iliac articulation to the anus. It is attached in its upper half to the posterior wall of the pelvis by a mesorectum, and slopes at first inwards and downwards, then lies in the mesial plane and follows the curve of the sacrum and coccyx till immediately above the sphincter and an inch or two beyond the coccyx, when it is directed abruptly downwards and backwards to the outlet. In the lower part of its curve it is considerably dilated, and being beyond the recto-vesical pouch, it is devoid of peritoneal covering. Here it has in the male the trigone of the bladder and the prostate gland resting in front of it, and in the female the vagina. The longitudinal fibres of the

muscular coat are strong, and cease to be gathered into bands, and are disposed pretty equally, as also are the circular fibres down as far as the recurved outlet, where they are accumulated in large quantity to form the *internal sphincter*. The mucous membrane presents a few crescentic folds (*valves of Houston*), the most prominent of them being situated in front, behind the prostate, and the next above it projecting from the posterior wall a little higher up. The constricted part within the grasp of the internal sphincter is thrown into longitudinal folds; and lower down than this the mucous membrane, covered with columnar epithelium, comes in contact with a thin prolongation upwards of integument with squamous epithelium of the cuticle. The line of termination of the mucous membrane is distinct and crenated; and between the crenations there run upwards some short narrow prolongations of integument about eight in number (*columns of Morgagni*) separating shallow depressions of the mucous membrane, which when engorged may become convex.

THE PANCREAS.

The pancreas is an elongated gland, of soft structure and lobulated appearance, not unlike a salivary gland. It lies across the posterior wall

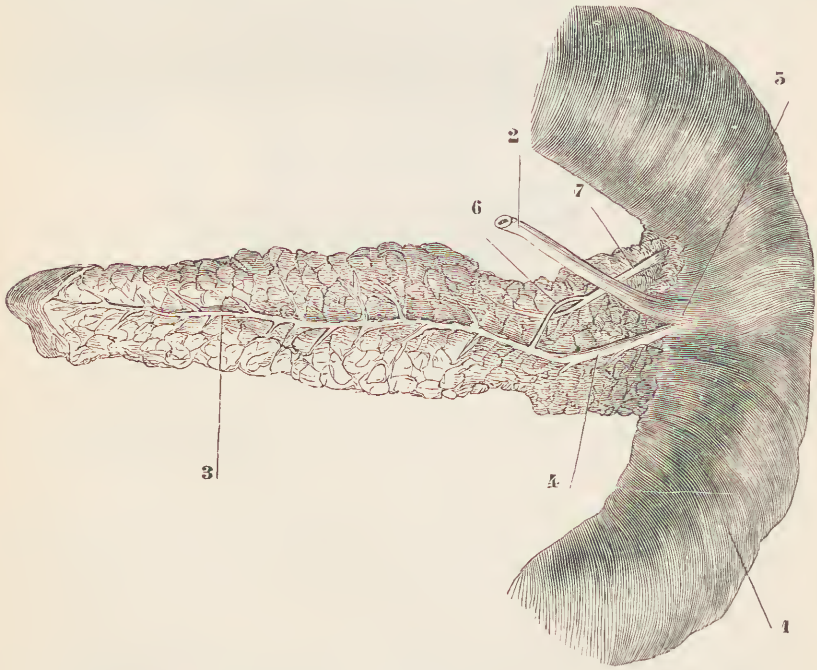


FIG. 564.—PANCREAS FROM BEHIND. 1, Duodenum; 2, common bile duct; 3, 4, 5, duct of Wirsung dissected out; 6, 7, communicating branch and accessory pancreatic duct. (Beaunis.)

of the abdomen, extending from the duodenum, whose loop it fills up, to the spleen, which it barely touches. The end embraced by the duo-

denum is broad, and is called the head; the greater part of the succeeding length is about an inch and a half broad, and is called the body; and the narrow extremity next the spleen is called the tail. With the exception of part of the head, it is clothed in front with peritoneum by the posterior wall of the smaller sac. It is in contact behind, from right to left, with the diaphragm, the inferior vena cava, the superior mesenteric vein and artery, the inferior mesenteric vein, the aorta and the left crus of the diaphragm; and close to its upper border is the splenic vein, partly concealed by it, with the splenic artery above it, as also the coeliac axis and hepatic artery.

Fig. 565.—Human Pancreas, $\frac{450}{1}$. (Böhm and v. Davidoff.)

The pancreas pours its secretion into the duodenum by a duct (*duct of Wirsung*) with thin non-muscular walls, which can be easily traced running in the middle of the gland in its whole length, receiving in its course numerous tributary ducts from above and below. The duct opens mainly or altogether into the descending part of the duodenum about four inches from the pylorus into a shallow depression on the posterior wall, common to it and the common bile-duct, having pierced the intestinal wall obliquely. Near its exit it receives a tributary from the lower part of the head, rather larger than the others, and often there is in addition a *superior* or *accessory duct* opening fully an inch above the main duct, to which it can be traced back.

The larger lobules of the pancreas consist of smaller lobules as in the case of a salivary gland. The acini are small in transverse section, and sometimes so elongated that some observers describe the pancreas as a

tubular or acino-tubular gland; but the same difficulty may with equal justice be raised with reference to other glands, as the parotid and Brünner's glands. The secreting corpuscles leave little central lumen, but a network of intercellular passages has been displayed by injection by various observers, and compared with the network of canals demonstrated in the liver. The secreting corpuscles are loaded with granules towards the centre of the acinus to such an extent as to add difficulty to their examination, and the number of granules is alleged to vary according to the period of digestion. Amoeboid corpuscles, *centro-acinary cells of Langerhans*, are frequent within the acini.

THE LIVER.

The liver is much the largest gland in the body, weighing ordinarily between 50 and 60 ounces in the adult male, and between 40 and 50 in the female. It is of a deep brown colour more or less mingled with claret colour according to the amount of blood which it happens to contain. Symmetrical, or almost so, in its earliest development, it occupies in the young foetus the whole upper part of the abdomen; but in consequence of the left side growing less rapidly than the right, it comes in the adult to occupy principally the right hypochondrium, stretching across the epigastrium to the left hypochondrium, which it invades to a small and variable extent. When laid out on a flat surface it is somewhat quadrate in form, thick behind, sharp-edged in front and to the sides, and decreasing both in thickness and in antero-posterior diameter toward the left, and it presents an unbroken dorsum looking upwards. But in the natural position within the body the differences in thickness of different parts are greater; for the dorsum not only lies against the diaphragm both behind and above, but descends on the right side to the level of the eleventh rib, and in front comes in contact with the transversalis abdominis, its anterior edge lying inside the seventh, eighth and ninth costal cartilages before sloping upwards across the middle line, and backwards in a manner varying somewhat in different persons and attitudes. The posterior surface is also formed in great part by the dorsum, and is deep and convex on the right, thinning to an edge toward the left. As it approaches the mesial plane it is thrown into a concavity by the projection of the vertebral column; and on the right side of this concavity, it presents a deep vertical groove for the inferior vena cava, which is firmly embedded in it, and receives the emerging veins termed *hepatic*, carrying the blood away from the liver.

The anterior edge is interrupted by two notches, one lying above the fundus of the gall-bladder, while the other, placed about an inch and a quarter more internally, but still situated about an inch to the right of the middle line, receives the obliterated umbilical vein, the *round ligament*, as it passes to the under surface. On each side of this ligament the peritoneum

extends upwards and backwards over the liver and the opposed surface of the diaphragm, thus forming a septum, the *falciform* or *suspensory ligament*, whose hepatic attachment corresponds with the division of the inferior surface into right and left lobes. The other peritoneal connections of the liver are the *coronary* and *right* and *left triangular ligaments*, and the attachment of the gastro-hepatic omentum (p. 689).

The inferior surface presents a number of **fissures** and **lobes**. The longitudinal fissure, dividing it into a *right* and a *left* lobe, extends from front to back, and consists of two parts, an anterior, the *fissure of the umbilical vein*, and a posterior, distinguished as the *fissure of the ductus venosus*, and also giving attachment to part of the gastro-hepatic omentum. The *portal*

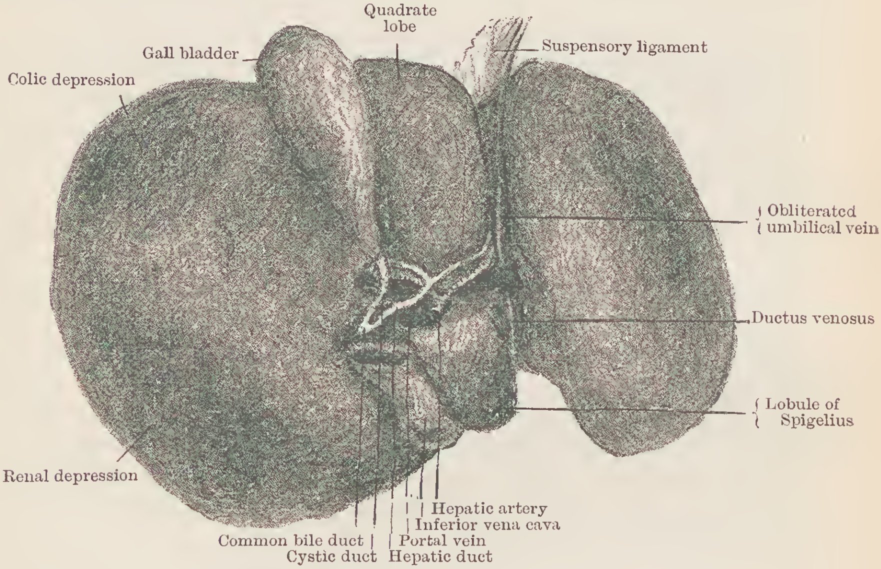


FIG. 566.—UNDER SURFACE OF LIVER.

or *transverse fissure* falls at its left extremity into the longitudinal, dividing it into its two parts, and at its right extremity meets the posterior end of the *fissure of the gall-bladder*, which extends forwards from it. Behind the right extremity of the portal fissure is the groove or *fissure of the inferior vena cava*, separated from it by a narrow elevation. The portal fissure is the site of attachment of the part of the gastro-hepatic omentum containing structures entering and emerging from the liver. The structures in question enter and emerge at its extremities and are the right and left branches of the hepatic artery, the right and left branches of the portal vein, the right and left hepatic ducts, together with nerves and lymphatics. At the left end of the portal fissure the obliterated umbilical vein ends in the left branch of the portal vein, and the obliterated ductus venosus starts from the same point to go backwards and upwards to join the inferior vena cava.

Three portions of the right lobe are named as separate lobes; and two of these, namely, the quadrate and the Spigelian lobes, are definitely bounded. The *quadrate lobe* is in front of the portal fissure and is between the fissure of the umbilical vein and the fissure of the gall-bladder. The *Spigelian lobe* is behind the portal fissure, between the vena cava inferior and the fissure of the ductus venosus; it projects downwards as a three-sided pyramid, and is much more elongated in many animals, and is always distinguishable as the only lobe looking into the smaller sac of the peritoneum. The *caudate lobe*, the third portion of the right lobe distinguished by the name of lobe, is merely a slight eminence outside the foramen of Winslow, and continuous with the narrow elevation separating the portal fissure from the vena cava inferior, but it is developed as a distinct lobe in many animals. The remaining part of the right lobe has a constant slight concavity toward the back, the *renal impression*, fitting over the right kidney, and another further forwards, the *colic impression*, lying over the hepatic flexure of the colon. The under surface of the left lobe exhibits a slight convexity corresponding with the smaller curvature of the stomach and a shallow concavity beyond over the fundus.

Main ducts and gall-bladder. The *right* and *left hepatic ducts*, emerging from the portal fissure, approach each other rapidly to form the hepatic duct, the right and left ducts joining in front of the right and left branches of the hepatic artery, while the portal vein bifurcates behind them, and lower down the hepatic duct lies to the right, the artery to the left, and the portal vein between and behind. The *hepatic duct* runs for about two inches and is met at an acute angle by the cystic duct. The duct resulting from the junction of the hepatic and cystic ducts is called the common bile duct (*ductus communis choledochus*) and continues in the same direction as the hepatic duct; it is about one sixth of an inch in diameter when distended, and is about three inches long. It passes down behind the descending part of the duodenum, between it and the head of the pancreas, pierces along with the pancreatic duct obliquely through the coats of the posterior wall of the duodenum, and opens by means of a constricted orifice into a slight depression common to it and the pancreatic duct, about four inches from the pylorus. The *gall-bladder* is pyriform, three or four inches long and about an inch and a quarter in diameter at its broadest part when moderately distended. Its fundus or broad extremity projects to a certain extent free at the notch in the overhanging margin of the liver, and it tapers backwards closely adherent to the floor of the groove in which it lies. It is continued into the *cystic duct*, which is about an inch and a half long, and turns downwards to join the hepatic duct. The mucous membrane of the gall-bladder has a fine reticulated pattern, throwing it into shallow honeycomb-like depressions visible to the naked eye and better seen with a lens. At the neck and in the cystic duct it is thrown into irregular folds liable to obstruct the passage of a probe.

Hepatic structure. The liver presents in section and even through its investments a mottled appearance, which, when more closely examined, resolves itself into closely-set lobules varying in diameter from the twenty-fifth of an inch to twice that size, and each presenting a paler spot surrounded with darker colour, or a dark spot surrounded with paler colour, according as the blood happens to be more abundant at the circumference or in the centre. The substance is friable, and torn surfaces exhibit lobules torn partially separate.

Beneath the peritoneal covering, which is transparent, there is a certain amount of connective tissue not very visible when healthy, but important pathologically, the seat of bloodvessels and lymphatics, and easily seen in section with the aid of the microscope: this is called the *fibrous* or *areolar capsule.* But a larger amount of areolar tissue enters at the portal fissure and invests the branches of the portal vein, hepatic artery and ducts, as well as nerves and lymphatics, which may be traced backwards together in branching hollows called *portal canals*; and this investment gets the name of *capsule of Glisson.* When the substance of the liver is cut across, the sections of the portal canals, each containing the loose white tissue of the capsule of Glisson and in it a more or less collapsed branch of portal vein, with a much smaller artery and still smaller duct, contrast with other gaping openings, namely, the sections of hepatic veins with their thin walls closely attached to the hepatic substance.

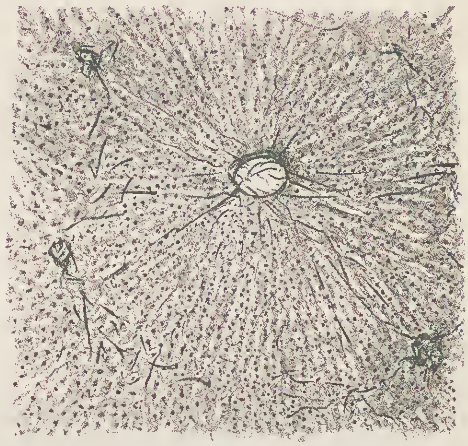


FIG. 567.—HEPATIC LOBULE MAGNIFIED, showing intralobular radicle of hepatic vein in the centre, and interlobular branches of the portal vein at its circumference. The grey lines are the columns of hepatic cells, the black spots their nuclei, the white spaces the lamina of the capillaries, the black lines the threads of white fibrous tissue hardened and stained.

Examined microscopically, each lobule presents in the centre a venous radicle called an *intralobular vein*, which falls into a *sublobular* branch of the hepatic vein; while, between the lobules, there are situated *interlobular* branches of the portal vein; but the texture appears principally composed of secreting corpuscles, the *hepatic cells.* These are unwalled polyhedral bodies, varying in size, but averaging $\frac{1}{1000}$th of an inch, pressed with flattened sides each against others; they are of yellowish colour and granular appearance, each containing one large spherical nucleus, and some of them two. They may also contain oil globules and coarse granules, which are not, however, part of their proper substance. The hepatic cells present a distinctly radiating arrangement in each lobule, but, when looked at more

closely, are seen to constitute a continuous mass filling up the whole space left between the blood-capillaries, which form a very regular network with meshes elongated in a radiating direction, so that the whole lobule may be looked on as consisting mainly of two networks interlaced, the one vascular, the other cellular. Both the capillary and the cellular network are continuous from one lobule to another, and, where the lobules meet, the radiating arrangement is lost.

There are mammals, especially the pigs, camels, and giraffe, which have the lobules distinctly separated by connective tissue, but in most animals they are not so separated; and in the human subject the connective tissue is so slight as to have been till recently somewhat overlooked. There is, however, both in the adult and the infant, a distinct set of isolated bands with netted branches uniting the tunica adventitia of the intralobular vein with the ultimate branches of Glisson's capsule and other fibres coursing between the lobules. An abundance of minute leucocytes or lymphoid corpuscles may be found in scattered groups, and stellate corpuscles have been described. Within the lobules there remains to be described a network of intercellular ducts or canals.

FIG. 568.—HEPATIC TISSUE HIGHLY MAGNIFIED. *A*, Capillaries and bile-ducts injected; *a*, capillary bloodvessels; *b*, intercellular ducts (after Hering); *B*, separate hepatic cells.

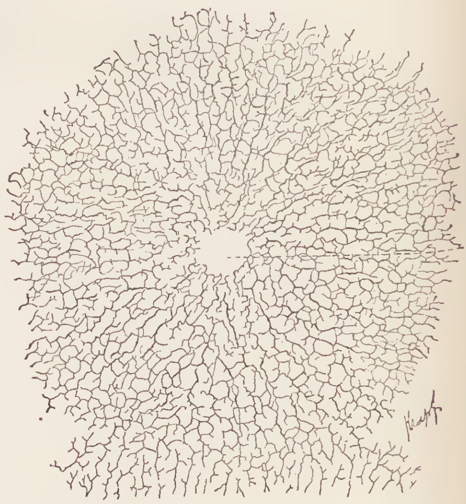


FIG. 569.—INTRALOBULAR DUCTS, silver chromate preparation. (Böhm and v. Davidoff.)

The ducts. Within the lobules there cease to be found any ducts lined with epithelium. The finest *interlobular ducts* have simple membranous walls lined with flattened cells which at the periphery of the lobules come into direct contact with the hepatic cells. But in the interior of the lobes there is a network of minute *intercellular canals* much finer than the capillary vessels, channelling the opposed surfaces of the hepatic cells, and only very

imperfectly to be made out save with the aid of injection. They were first observed by means of coloured fluid injected backwards, but considerable doubt was felt by many until Chrzonszezewsky (1866) put an end to all question of their existence as canals during life, by his process of "natural injection," which consisted of introducing solution of indigo into the veins of an animal, when, in consequence of this substance being eliminated from the blood by the liver, injection of the intralobular canals was got by the action of the hepatic cells. These were found full of indigo when the animal was at once killed, but clear when the killing was delayed half an hour. Later researches, particularly by means of the Golgi method, have not only extended the acquaintance with the intercellular passages, but traced their origins from tributaries within the hepatic cells. Only the finest interlobular ducts have flattened epithelium; the rest are lined with columnar cells, and the *larger ducts* have a mucous membrane distinct from the outer

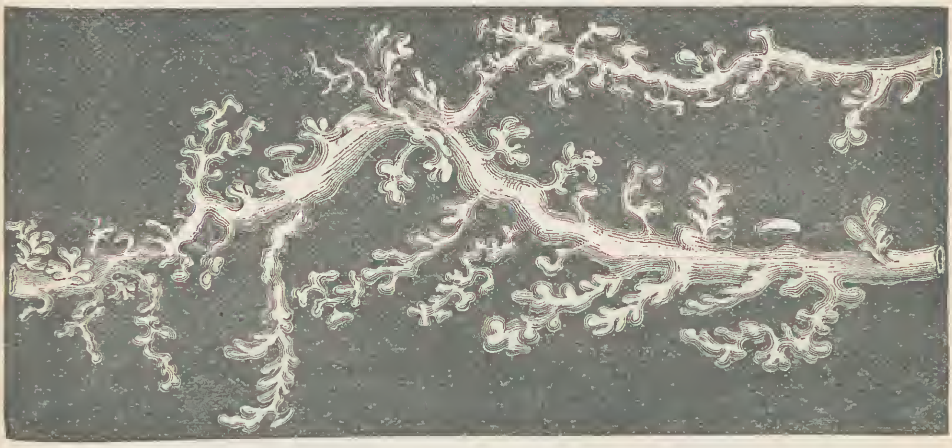


FIG. 570.—ABERRANT DUCTS WITH BLIND GLANDULAR-LOOKING OFF-SHOOTS, from the fissure of the ductus venosus, $\frac{50}{1}$. (Luschka.)

wall. The outer wall of the larger ducts contains a certain amount of muscular fibres, especially those outside the liver, and the gall-bladder has a still more distinct muscular wall arranged in longitudinal and circular layers. The main ducts are beset with numerous branched pouches secreting mucus, which in the ramifications within the liver become simple and arranged in two rows, and in the smaller ducts are absent. Remarkable networks of gall-ducts without hepatic substance around them, but accompanied with twigs of portal and hepatic veins, *vasa aberrantia*, are found in the portal fissure, in a membrane joining the right and left hepatic ducts, and continued thence in the fissure of the umbilical vein, the fissure of the ductus venosus, round the vena cava inferior and into the left triangular ligament. The larger of these vasa aberrantia have mucous pouches like the other ducts. They are absent in the new-born child (Toldt).

The hepatic artery after entering the liver ramifies in the portal canals,

and its terminal branches are termed *interlobular*. But in its course it gives off *vaginal* branches to the other structures in the capsule of Glisson and *capsular* branches which pass to the surface and ramify in the capsule of the liver, often in stellate fashion. The lobules of the liver can be injected from the hepatic artery, but the injection always enters the lobules from the centre, and the probability is that it is taken up by radicles of the hepatic vein in Glisson's capsule, and is sent backwards when exit by the inferior vena cava is blocked.

The lymphatics of the liver are deep and superficial. The deep lymphatics emerge by the portal fissure; the superficial lymphatics form a plexus of remarkable closeness whose vessels principally join the deep lymphatics at the portal fissure, but also communicate with the parietal lymphatics in the ligaments.

The nerves are principally sympathetic, the hepatic branches of the coeliac plexus; but filaments can be followed into the liver from the pneumogastric nerves.

DEVELOPMENT OF STOMACH, INTESTINE AND LIVER.

The part of the foregut within the grasp of the visceral arches forms a dilated pharyngeal pouch (pp. 94 and 99). The stomach makes its appearance immediately beyond this, as a spindle-shaped mesial structure, but descends as the heart descends, its descent giving rise to the oesophagus. The pylorus being the first part to be arrested in its downward movement, the stomach is bent and its dorsal surface thrown to the left, when the surface originally placed to the left is turned to the front. Meanwhile

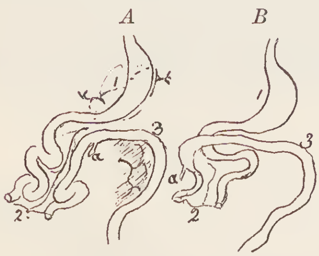


Fig. 571.—Diagrams of Stomach and Intestine in Third Month. *A*, Before the colon has crossed over the duodenum; *B*, after the crossing; 1, 2, 3, the coeliac, superior mesenteric and inferior mesenteric loops; *a*, the caecum.

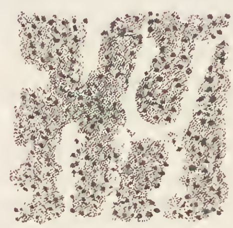


Fig. 572.—Section from Liver of Foetus of Five Months, showing from three to seven corpuscles abreast between adjacent capillaries.

the part of the intestine succeeding the stomach is lengthened into a loop projecting ventrally with the umbilical duct coming off from its turning-point, which during the second month reaches out beyond the abdominal wall. The lower end of this *primary loop* becomes approximated to the pylorus and forms the part of the transverse colon which remains permanently in this connection. The caecum and vermiform appendage make their appearance close to this point, and push their way over the upper

limb of the loop, turning it round, as they travel first to the right and then downwards. This twist of the loop is not, however, altogether due to travelling of its lower limb, for the base of its upper limb is at the same time elongated semicircularly to form the duodenum. The part of the intestine beyond the primary loop, at first straight, becomes arched and thrown over to the left side by elongation of its mesocolon, which in the third month is still mesial, the descending colon being merely in contact with the left side of the posterior wall of the abdomen, but not at that date attached to it. The smaller sac of the peritoneum is originally simply the right side of the mesogastrium. By the turning of the stomach on its side, and the descent of its oesophageal extremity, the mesogastrium becomes pouched, and the pouch so begun increases in size but is at first quite independent of the colon. Afterwards the inferior wall of the mesogastrium and the left wall of the mesial mesocolon become pulled away from the posterior wall of the abdomen near the middle line, and this brings the transverse colon into connection with the smaller sac of the peritoneum.

The liver makes its first appearance close to the pylorus as a bifurcating protrusion or, more correctly, a pair of protrusions from the ventral aspect of the intestine, which elongate in close connection with the omphalo-mesenteric veins. In mammals it would seem that those protrusions commence after the stomach has begun to turn on its side, and the left protrusion appears first. Each protrusion sends out ramifying branches which go on dividing, and the hepatic cells are derived from the hypoblastic corpuscles within the ramifications, and are thus similar in origin to the secreting cells of other intestinal glands. Subsequently the processes anastomose, while they still give off side-shoots, and outgrowing branches from the vitelline vein form a network interlacing with them, and developing into a system of *venae advehentes* and *revehentes*, which result in the portal and hepatic veins. In later development there is still considerable difference from the adult arrangements. In a foetus of five months, adjacent capillaries have still a number of hepatic cells between them, and even at birth the columns of cells in the lobules are more liable to present two or three abreast than afterwards.

The pancreas in the vertebrata generally is now known to take rise from three distinct intestinal outgrowths—a dorsal opposite the biliary protrusion, and two ventral, right and left of it.

THE RESPIRATORY ORGANS.

Leaving out of consideration the nasal passages and mouth, the respiratory organs consist of larynx, trachea and bronchi, and the lungs, in which the bronchial tubes, continuous with the bronchi, pursue their course to the air-cells.

THE LARYNX.

The larynx is the upper part of the wind-pipe, modified in connection with the production of voice and protection from foreign bodies. It presents a special arrangement of cartilages, ligaments, muscles and mucous membrane, the general character of which is that a firm ring, the cricoid cartilage, furnishes the base on which the thyroid cartilage in front and the arytenoid cartilages behind are raised and depressed, so as to alter the position and tension of two lateral folds of mucous membrane, the true vocal cords, which project from the floors of two ventricles, and by their approximation and vibration produce the voice, while the aperture is overhung by the epiglottis and other structures for protection.

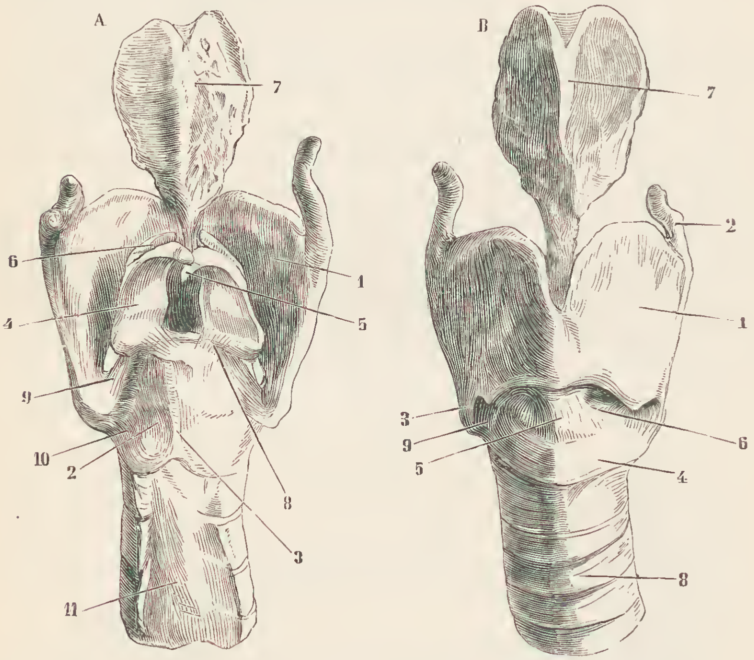


FIG. 573.—CARTILAGES OF LARYNX. *A*, From behind: 1, thyroid cartilage; 2, depression on the cricoid cartilage for posterior crico-arytenoid muscle; 3, median crest of cricoid; 4, arytenoid; 5, cartilage of Santorini; 6, cartilage of Wrisberg; 7, epiglottis; 8, posterior crico-arytenoid ligament; 9, 10, upper and lower posterior kerato-cricoid ligament; 11, posterior wall of trachea. *B*, from the front: 1, thyroid cartilage; 2, 3, its upper and lower cornua; 4, cricoid cartilage; 5, crico-thyroid ligament; 6, lateral part of the same, continued into the crico-thyro-arytenoid membrane; 7, epiglottis; 8, trachea; 9, anterior kerato-cricoid ligament. (Beaunis.)

Cartilages. The cricoid cartilage is a strong and complete ring. Its inferior border is horizontal and continuous with the trachea, while the upper border rises with a concavo-convex curve on each side from before backwards, so as to give a height behind more than three times greater than in front. The posterior elevated part is likewise thicker, and placed on it are two convex articular surfaces for the arytenoid cartilages. These

surfaces look upwards, and have an interval of about quarter of an inch between them. On each side, placed well back, and about the level of the fore part of the upper border, is a slightly elevated circular articular surface for the inferior cornu of the thyroid cartilage. On the posterior surface there is a vertical mesial ridge, and an impression on each side of it for the posterior crico-arytenoid muscle.

The thyroid cartilage, the largest and most prominent cartilage of the larynx, is a plate consisting of two symmetrical alae, widely separate behind and united in the middle line in front, the line of junction of the two halves being the narrowest portion, and projecting superiorly so as to form the prominence called *pomum Adami*. From this point the upper border on each side at first curves upwards, commencing an S curve which ends behind in a long process, the *superior cornu*. From the tip of this cornu the posterior border descends in a straight line to the tip of the *inferior cornu*. The inferior cornu is shorter than the superior, and at its extremity has a small circular surface looking inwards to articulate with the cricoid cartilage. On the external surface of the thyroid cartilage an oblique line, slightly prominent, extends downwards and forwards, separating the insertion of the sterno-thyroid from the origin of the thyro-hyoid muscle, and ending inferiorly in an overhanging tubercle.

Fig. 574.—Mesial Section of Larynx. *a*, Hyoid bone; *b*, *c*, *d*, thyroid, cricoid, and arytenoid cartilages; *e*, true vocal cord; *f*, false vocal cord, and beneath it the ventricle of the larynx; *g*, epiglottis; *h*, tongue.

The arytenoid cartilages present each three elongated sides ascending from a triangular base to a pointed summit which is curved backwards. Of the three sides, one looks backwards and is concave from above downwards, another looks inwards and is flat, while the third, looking forwards and outwards, is convex. The base has a slightly concave surface for articulation with the cricoid cartilage; its outer angle (*processus muscularis*) is prominent, and its anterior angle (*processus vocalis*) is prolonged, giving attachment to the inferior thyro-arytenoid ligament.

The cornicula laryngis, or *cartilages of Santorini*, are two small nodules on the summits of the arytenoid cartilages.

The cuneiform cartilages, or *cartilages of Wrisberg*, are still smaller, soft and yellowish, placed outside and in front of the cornicula, in the aryteno-epiglottidean folds.

The epiglottis is an obcordate plate of yellow cartilage. Its narrow and elongated inferior extremity is connected by means of loose elastic tissue with the interior of the thyroid cartilage as far down as the vocal cords, and with the hyoid bone and the raphe of the tongue. Its upper part projects free, the mucous membrane being reflected upwards on it

from the tongue, and presenting a mesial and two lateral *glosso-epiglottidean fraenula* with shallow depressions between. The sides of this upper part are folded back round the front of the laryngeal opening. The laryngeal surface is closely invested with mucous membrane in its whole extent and deeply pitted with mucous glands, and presents in its lower half a distinct convexity, the *pulvinus*, which lies over the glottis when the epiglottis is depressed by the movement of the tongue and contraction of the thyro-hyoid muscles in swallowing.[1]

Joints and ligaments. The thyroid cartilage is attached to the cricoid by a pair of synovial joints and a crico-thyroid ligament. The *crico-thyroid articulation* has, besides a synovial capsule, three ligaments spreading in different directions, the *anterior* and the *upper* and *lower posterior kerato-cricoid ligaments*, and admits of only one description of movement, namely, revolution round an axis passing through the joints of opposite sides. The *crico-thyroid ligament* is thick and strong, and consists of yellow-elastic fibres spread out at their attachment to that part of the upper border of the cricoid cartilage left uncovered by the thyroid cartilage, and converging as they ascend to be inserted into the deep surface of the mesial part of the thyroid cartilage. A small pit or perforation is left in the middle line, and the lateral border is continued into a much thinner structure, the *crico-thyro-arytenoid* membrane, which arises from the inner lip of the remainder of the upper border of the cricoid cartilage as far back as the arytenoid cartilage, and is continued in contact with the mucous membrane up to the true vocal cord.

Fig. 575.—Larynx, from above; laryngoscopic views. A, In deep respiration, showing the trachea down to its bifurcation; B, in uttering a high pitched note. *a*, Epiglottis; *b*, *c*, swellings corresponding to cartilaginous nodules of Wrisberg and Santorini; *d*, true vocal cord; *e*, false vocal cord. (After Czermak.)

The thyroid cartilage is attached to the hyoid bone by two ligaments and an intervening membrane. The *lateral thyro-hyoid ligaments* are two rounded cords, somewhat elastic, extending on each side from the tip of the superior cornu of the thyroid cartilage to the extremity of the great cornu of the hyoid bone, and sometimes containing one or more cartilaginous

[1] The epiglottis unquestionably comes like a lid over the larynx in swallowing, notwithstanding that Professors Anderson Stuart and M'Cormick of Sydney record a case where food glided over the upper part of its laryngeal surface, after an operation, in which the hypoglossal nerve was admittedly destroyed, and the glosso-pharyngeal may have been (*Journal of Anatomy and Physiology*, Vol. XXV.).

nodules (*cartilagines triticeae*). The *thyro-hyoid membrane* extends from side to side between the ligaments, and is perforated on each side by the superior laryngeal artery and nerve. In front of it, in the middle line, there is a bursa between it and the posterior surface of the hyoid bone; it is pretty constant and may be prolonged linearly to near the thyroid cartilage.

The *crico-arytenoid articulation* is a synovial joint with a capsule and a strong triquetrous posterior ligament, whose fibres spread upwards and outwards. This joint permits two sets of movements, namely, angular movement, by which the arytenoid cartilages are raised and depressed, and rotation round a vertical axis, by which the vocal cords are brought together and separated.

FIG. 576.—ANTERIOR HALF OF LARYNX FROM BEHIND. (Pansch.)

The *superior* and *inferior thyro-arytenoid ligaments* consist each of a small number of elastic fibres, the superior lying in the fold called the false vocal cord, and the inferior, more distinct, placed in the margin of the true vocal cord, strengthening the thickened upper border of the crico-thyro-arytenoid membrane already described.

Laryngeal cavity and mucous membrane. The entrance into the larynx is bounded on the sides by the *aryteno-epiglottidean folds*, which stretch from the epiglottis, at its broadest part, to the cornicula laryngis. The cornicula incline over into the pharynx, and between them the edge of the larynx is depressed in the spout-like fashion which has earned to the arytenoid cartilages their name. The sides of this depression are bounded by two rounded little swellings caused by the cornicula, and two others beyond

them correspond with the cartilages of Wrisberg. In the interior of the larynx, in front of the bases of the arytenoid cartilages, the cavity is narrowed between the vocal cords, and the narrow part is called the *glottis*, *rima glottidis* or chink of the glottis, the passage being reduced to a mere chink when the vocal cords are approximated; but even then the back part of the glottis between the two arytenoid cartilages presents a gap. Below the glottis the sides of the cavity slope smoothly out to the full breadth of the trachea beyond; but immediately above it there is on each side a recess, the floor of which is horizontal, forming the upper surface of the *true vocal cord*, and limited above by the arched margin of the *false vocal cord*. This recess is called the *ventricle* of the larynx, and toward the front has a prolongation upwards called the *saccule*, in contact with the thyroid cartilage.

The mucous membrane of the larynx is thin and firm. The submucous tissue of the aryteno-epiglottidean folds is loose, capable of being swollen up by oedema. The squamous epithelium of the fauces is exchanged for ciliated columnar stratified epithelium a little below the margin of the aryteno-epiglottidean folds; and with this the whole of the rest of the larynx, as well as the trachea and bronchi, is lined, save only the true vocal cords, which are clothed with stratified squamous epithelium. Taste-bulbs, similar to those of the tongue, are found on those parts of the epiglottis and aryteno-epiglottidean folds which have stratified epithelium, parts which are exceptionally sensitive. The mucous membrane is pierced by the ducts of mucous glands, of which one group, epiglottidean, lies in the pits of the epiglottis; others are in front of the arytenoid cartilages and above the false vocal cords, and a number open into the saccule.

Muscles. The *crico-thyroid* muscles arise one on each side of the middle line from the fore part of the cricoid cartilage, and the fibres of each diverge as they pass upwards and outwards to be inserted into the inferior edge of the thyroid cartilage as far back as the tip of the inferior cornu, leaving only a space of about half an inch between the two muscles in front. By their contraction these muscles approximate the cricoid and thyroid cartilage in front, and thus make tense the vocal cords in raising the pitch of the voice. If the tip of the finger be placed over the space between the thyroid and cricoid cartilages the space will be felt to be diminished in singing high notes and increased in singing bass notes.

The *posterior crico-arytenoid* muscles arise fleshily from the whole of the depressed portion of the posterior surface of the cricoid cartilage external to the mesial ridges, and extend upwards and outwards, the fibres of each converging to be inserted into the back of the processus muscularis of the arytenoid cartilage. They rotate the external angles of the arytenoid cartilages inwards, and thereby rotate outwards the anterior angles on the cessation of vocalization. Plainly also they re-elevate the arytenoid cartilages when they have been depressed.

The *lateral crico-arytenoid* muscles arise one on each side from the whole

lateral part of the upper border of the cricoid cartilage, and the fibres converge from this origin to the front of the outer angle of the base of the arytenoid cartilage of the same side. They rotate the outer angles of the arytenoid cartilages forwards and the anterior angles inwards so as to approximate the vocal cords to the middle line; and they come into action in every act of vocalization.

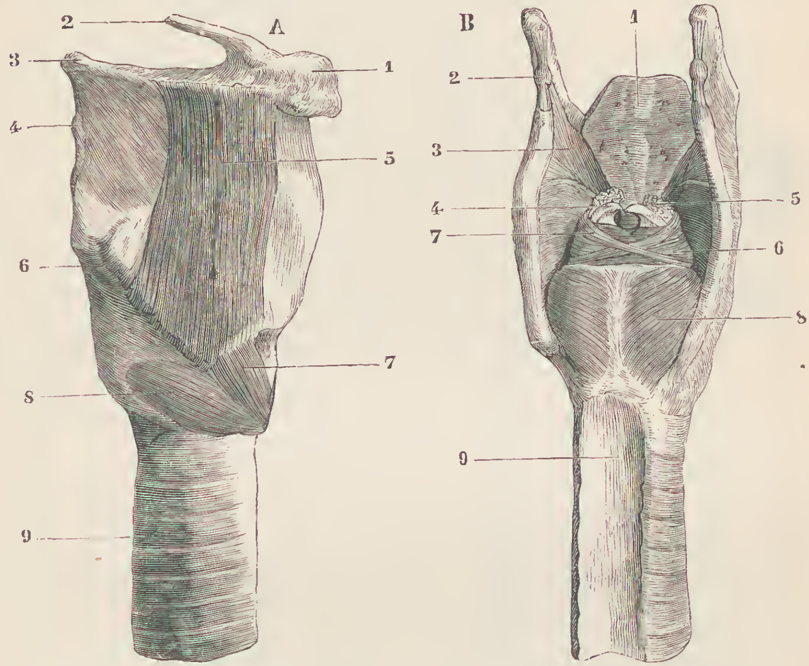


FIG. 577.—MUSCLES OF LARYNX. A, From right side: 1, 2, 3, body, small cornu and great cornu of hyoid bone; 4, thyro-hyoid membrane; 5, thyro-hyoid muscle; 6, upper end of the oblique line separating the thyroid attachments of the inferior pharyngeal constrictor and the thyro-hyoid muscle; 7, 8, anterior and posterior fibres of crico-thyroid muscle; 9, trachea. B, From behind: 1, epiglottis; 2, triticeal cartilage; 3, thyro-hyoid membrane; 4, cartilage of Santorini; 5, arytenoid group of mucous glands; 6, arytenoideus muscle; 7, aryteno-epiglottideus muscle; 8, posterior crico-arytenoid muscle; 9, trachea. (Beaunis.)

The *thyro-arytenoid* muscle of each side has its inferior and outer fibres in contact with the foremost and longest fibres of the lateral crico-arytenoid muscle, but above these it is divided into an external and an internal part, the external part lying against the outer wall of the ventricle and above it, while the internal part is in its floor, within the fold of the true vocal cord. The inferior fibres arise in part from the side of the crico-thyroid ligament immediately below the thyroid cartilage; the rest arise from the thyroid cartilage, close to the front of the crico-thyro-arytenoid membrane. The external part is inserted behind into the outer margin of the arytenoid cartilage; and the internal part into the lower portion of the anterior surface of that cartilage.

Though thus divisible into parts, variously described by different authors,

the thyro-arytenoid muscles have a very distinct action, namely, to approach the front of the thyroid cartilage to the arytenoids. They therefore come into action in the production of deep notes. The approach of the bases of the arytenoid cartilages to the thyroid being effected by revolution of the cricoid cartilage on the inferior cornua of the thyroid, the crico-thyroid space is enlarged, as can be felt with the finger in making a deep note. Thus the thyro-arytenoidei are the opponents of the crico-thyroidei muscles.

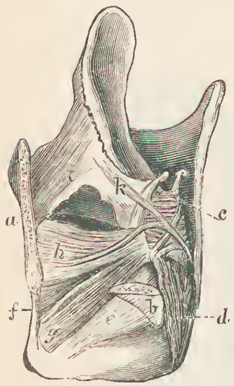


Fig. 578.—Larynx from the Left and Behind. *a*, Section of thyroid cartilage, the left side of which is removed with the exception of *b*, the part articulating with the cricoid cartilage; *c*, arytenoideus muscle; *d*, posterior crico-arytenoideus; *e*, crico-thyroideus; *f*, crico-thyroid ligament; *g*, crico-arytenoideus lateralis; *h*, thyro-arytenoideus, its upper edge corresponding with the edge of the vocal cord; *i*, *k*, thyro- and aryteno-epiglottideus, resting on the aryteno-epiglottidean fold of mucous membrane. A portion of the mucous membrane is removed between *h* and *k* to show the position of the glottis.

The *arytenoid* muscle is a single muscle whose transverse fibres cross the middle line, being attached to the posterior surfaces of the arytenoid cartilages.

The *aryteno-epiglottidean* muscles are two long slips which, arising one behind each processus muscularis, decussate in the middle line, and, turning each round the summit of the opposite arytenoid cartilage, extend into the aryteno-epiglottidean fold beyond. Fibres may take origin from the arytenoid cartilage as they turn round it, and sometimes the fibres on the surface of the arytenoid muscle are absent.

The *thyro-epiglottidean* muscles consist of fibres of the same sheet as the external part of the thyro-arytenoid muscle, arising higher from the thyroid cartilage external to the saccule and passing upwards and backwards to the aryteno-epiglottidean fold.

Two pairs of *hyo-epiglottidean* muscles have been described by Macintyre (*British Medical Journal*, 15*th September*, 1888), one pair arising near the middle line, from the body of the hyoid, and the other arising from the great cornua, and both inserted into the dorsum of the epiglottis near its base.

Vessels and nerves. The superior laryngeal artery enters the larynx by piercing the thyro-hyoid membrane along with the superior laryngeal nerve. It is given off by the superior thyroid, which also supplies the crico-thyroid muscle, its crico-thyroid branch anastomosing with its fellow, in front of the crico-thyroid ligament. The inferior laryngeal artery enters the larynx in company with the recurrent laryngeal nerve beneath the inferior constrictor of the pharynx. The laryngeal nerves are branches of the vagus; the superior laryngeal supplies the mucous membrane, and before entering the larynx gives off the external laryngeal to supply the crico-thyroid muscle, while the other muscles are supplied by the recurrent laryngeal.

THE TRACHEA.

The trachea is continuous with the larynx and ends by dividing into the two bronchi for the right and left lungs. It is about $4\frac{1}{2}$ inches in length and $\frac{3}{4}$ inch or more in breadth, but is capable of elongation by elasticity, and of diminution in diameter by muscular contraction. Its commencement is opposite the lower border of the fifth cervical vertebra, and its termination in the adult is opposite the lower border of the fourth dorsal vertebra. It lies in the middle line, and rests on the oesophagus. At its commencement it is covered at the sides by the lobes of the thyroid body; and it is crossed by the isthmus of the thyroid body, opposite the second and third rings. Beneath this is the spot usually chosen for tracheotomy; and here the trachea has in front of it a layer of deep cervical fascia stretched between the sterno-hyoid and sterno-thyroid muscles, and separated from it the further it descends by a greater depth of loose tissue. In this tissue lie the inferior thyroid veins and the *ima thyroidea* artery when it is present; and at the sides are the common carotid arteries, the right artery further forward than the left. The trachea terminates opposite the lower border of the fourth dorsal vertebra, with the arch of the aorta in contact with it in front and on the left side. The branches of the arch are in close contact with it, the innominate to the right of the middle line, and the left common carotid and subclavian on the left side. The recurrent laryngeal nerves ascend in contact with it, in the angle between it and the oesophagus.

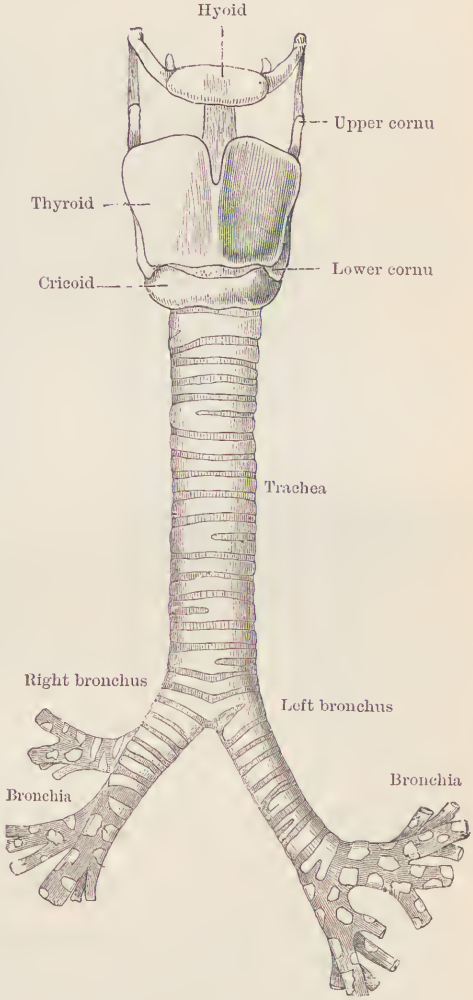


FIG. 579.—AIR-TUBES FROM BEFORE. (Pansch.)

The trachea is strengthened on its front and sides by cartilaginous bands

or incomplete *rings*, from about sixteen to twenty in number, with rectangular extremities resting on the oesophagus. These rings are not quite regular, some being single at one end and double at the other, and occasionally two being joined together in the middle. The lowest has a branch descending in the middle, separating the two bronchi. They are flat on their superficial aspect, and more convex on the deep.

The rings are joined together by a distinctly elastic fibrous membrane surrounding their perichondrium, and forming a continuous sheet behind. On removing the fibrous membrane at the back, a layer of unstriped muscle is brought into view, arranged in transverse bundles attached to the fibrous membrane inside the extremities of the cartilages and also between them. Loose tissue lies between the muscular layer and the mucous membrane, but, except at the back part, is very limited in amount. The proper substance of the mucous membrane is very thin and firm, and in close contact with the deep surface there is a strong coat of longitudinal yellow-elastic fibres visible with the naked eye, forming bands internal to the cartilages, and still stronger behind, where they give the interior of the trachea a characteristic longitudinally striated appearance. The epithelium is stratified columnar ciliated, the deepest corpuscles small and rounded, those of the intermediate stratum spindle-shaped, prolonged at both extremities into a thread, while the superficial corpuscles are elongated and ciliated.

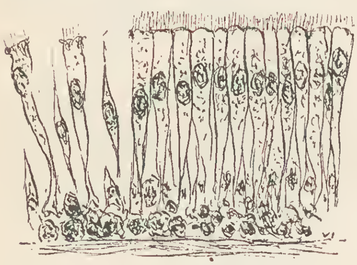


Fig. 580.—Vertical Section of Epithelium of Trachea.

The surface is studded with openings of ducts of small lobulated glands, the largest of which are in the posterior wall and are seen in the dissection of the fibrous and muscular layers. Those on the front and sides open between the rings, and occupy the depressions between successive rings, spreading on the deep side of their upper and lower margins. The acini are mostly, but not all, of the mucous character, and the secreting cells elongated columnar.

THE LUNGS.

The lungs correspond in general form with the pleural cavities, being convex laterally, posteriorly and superiorly, but hollowed out internally where in contact with the pericardium, and inferiorly where they rest on the diaphragm. They present each a sharp edge in front intruded between the pericardium and the thoracic wall, and another surrounding the *base* or diaphragmatic surface, so as to separate it from the external, internal and posterior surfaces. The upper part or *apex* reaches up through the first costal arch so far as to have in front of it, above, the subclavian artery where that vessel arches outwards in the first part of its course.

The posterior surface is the longest, lying in the vertebral fossa and continued gradually into the external and internal surfaces; and the greatest volume of lung is behind, immediately above the highest level of the diaphragm. The whole lung is invested with pleura except at the root and the part opposite the attachment of the broad ligament below the root (p. 686).

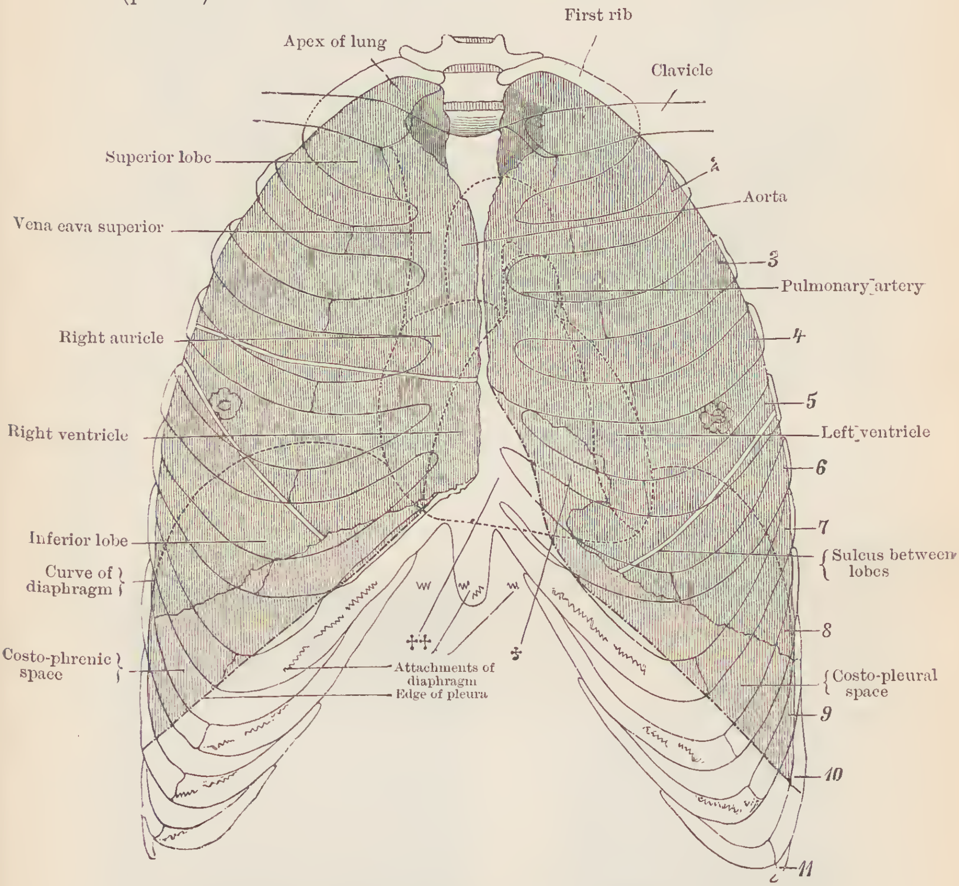


FIG. 581.—POSITION OF THORACIC VISCERA. †, Cardiac incisura of left lung; ††, where pericardium touches the thoracic wall. (Pansch.)

The *root* of the lung is the part where it is continuous with other parts, and consists of bronchus, right or left pulmonary artery and pulmonary veins, together with bronchial vessels and lymphatics and nerves. It is situated on the inner surface of the lung, nearer the back than the front, and above the middle. The phrenic nerve descends in front of it, and the pneumogastric behind it. The pulmonary veins emerge in front of the corresponding arteries and at a lower level, while the bronchus and bronchial vessels are behind.

The right and left lung differ one from the other in the number of lobes,

in shape and in weight, as well as in the arrangement of the large air-tubes. The right lung has three lobes and the left only two. The lobes are separated one from another by deep fissures into which the pleura extends. In both lungs a deep fissure passes inwards and somewhat upwards from a line which cuts the surface, beginning behind between two and three inches from the apex, and extending downwards and forwards to the base near the anterior edge; and by this means the inferior lobe is defined in both lungs. But on the right lung there is an additional fissure which begins from the first mentioned fissure more than midway back, and cuts the outer surface in a nearly horizontal direction so as to separate a *middle lobe* from the lower and fore part of the upper. This separation of the upper from the middle lobe often falls short of the anterior edge and is never as complete as the separation of the inferior lobe, although we shall find that in its bronchial arrangements the middle lobe is more closely connected with the inferior. The right lung has less vertical height than the left, for though the apex usually reaches a little higher than that of the left lung, the base is raised by the bulk of the liver below it. On the other hand, the weight of the liver offers an obstacle to pathological diminution of height of the right lung which is not offered by the stomach to the diminution of the height of the left lung. The right lung is much less hollowed out on its inner surface by the heart than is the left, and its anterior edge approaches the middle line or slightly crosses it. The left lung is excavated by the heart, both on its inner surface and at its anterior edge, where the upper lobe retreats above the apex of the heart and turns forwards below in a tongue-like process round it. The average weight of the right lung, as compared with the left, has been estimated as being about twenty-two ounces compared with twenty.

Internal structure. Healthy lung-substance is spongy, easily compressed between the fingers, but recovering its form immediately. It gives, on pressure, a peculiar sensation termed crepitation, due to the movement of air in minute spaces. When air is blown in by the wind-pipe it is seen to expand the substance of the lung in every part, and to be forcibly expelled by the elasticity of the minute texture, unless the wind-pipe be thoroughly closed. But even in the collapsed state the lung-substance is permeated with air, which cannot, without much difficulty, be perfectly removed; and hence it floats in water, and when cut presents a frothy section.

The proper texture of the lung is white, but it is tinged to a variable extent according to the amount of blood which it contains, and has its white converted into a grey appearance by deposits of black substance. Only once have I met with a pair of adult human lungs absolutely devoid of such deposits; often they are in such abundance as to make the lungs very dark, even if we keep out of consideration colliers' and knife-grinders' lungs which have been subjected to the inhalation of solid particles of a comparatively coarse description. When the deposits are moderate in

amount, they are most abundant in the planes of contact of the lobules of which the lung is made up; and on the surface they mark by polygonal lines the bases of the lobules, and extend into the deeper parts of the pleura. They consist of amorphous granules irregularly aggregated, unsur-

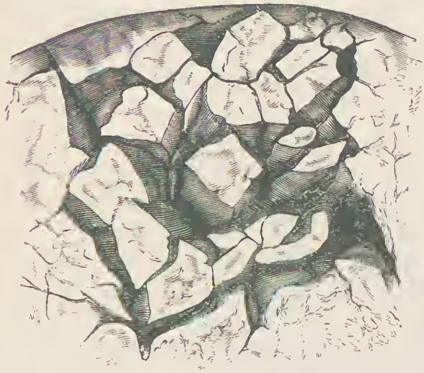


FIG. 582.—LOBULES OF LUNG. Separated one from another after removal of the pleura.

FIG. 583.—PULMONARY ALVEOLI HIGHLY MAGNIFIED. *a*, Denuded elastic partitions; *b*, denuded alveoli; *c*, simple squamous epithelium lining alveoli; *d*, epithelium covering the partitions.

rounded by cell-walls, and affecting rather the tissue between the air-spaces than the walls of these; and that they are independent of the textural elements appears to be shown by their being found abundantly in the lymphatic glands into which the lungs pour lymph.

FIG. 584.—FINEST AIR-TUBES WITH INFUNDIBULA AND ALVEOLI, from child at birth, $\frac{14}{1}$. (Luschka.)

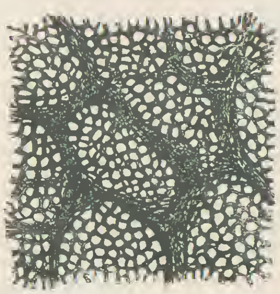


FIG. 585.—CAPILLARY INJECTION OF WALLS OF ALVEOLI.

The lung consists of a multitude of *lobules*, each of which receives air by a single *bronchial tube*, and has an air-system quite independent of others

when not united adventitiously with them by the pathological breaking down of septa, namely, by emphysema. But the lobules are only to a limited degree separable in the adult, although those which abut against the surface can often be isolated to a much greater extent than usually supposed. They are pressed together so as to have flat sides and an irregular polygonal form, and their diameters may vary from a quarter to two-thirds of an inch. The bronchial tube of each lobule divides into smaller tubes or *bronchioles* supplying smaller lobules, which are composed

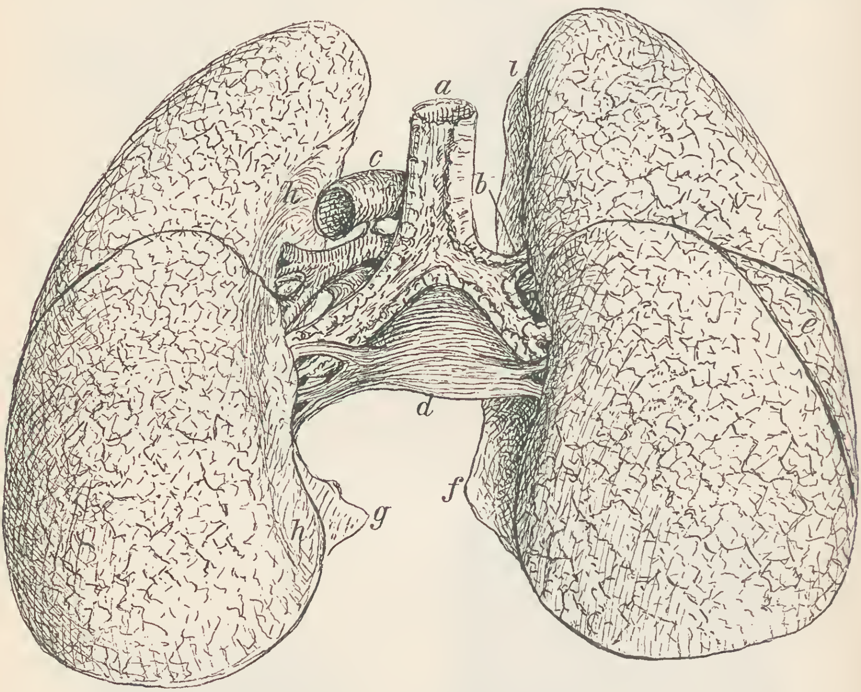


FIG. 586.—THE LUNGS FROM BEHIND. *a*, Trachea; *b*, branch of right bronchus for upper lobe of right lung; *c*, arch of aorta united by obliterated ductus arteriosus to commencement of left pulmonary artery; *d*, left auricle receiving from each side the pulmonary veins; *e*, middle lobe of right lung; *f*, *g*, anterior inferior angles of the two lungs; *h*, *h*, groove where the aorta lies against the left lung; *i*, groove where superior vena cava lies against right lung.

of groups of *ultimate lobules* or *infundibula.* Each infundibulum consists of an ultimate or respiratory bronchiole, which may be as small as one-fiftieth of an inch, and expands into an irregular passage which dilates and is walled all round by hemispherical *alveoli* or *air-cells.* The alveoli have a framework of elastic tissue, specially strong at the edges which separate them one from another. Spread out in this framework is a single layer of large capillaries forming a close network, the capillaries being about one-thousandth of an inch in diameter and the meshes not much wider; and in the septa between the alveoli one layer of capillaries is exposed to the air on both sides. Lining the interior of the alveoli there is a single

layer of very thin delicate squamous epithelium, which is exchanged at the free margins for much smaller, thicker, but still squamous cells, which are also found in the ultimate bronchioles.

The bronchi and bronchial tubes. The trachea divides into two bronchi, one for each lung. The right bronchus is somewhat larger than the left. The left bronchus slopes more downwards than the right (though an opposite statement has been made), the right forming an angle of 60° with the perpendicular, and the left an angle of 40° (Macalister). The vena azygos turns forwards over the right bronchus; the arch of the aorta passes back over the left. The bifurcation of the trachea is in the mesial plane, but the left lung is kept by the aorta and heart more away from the mesial plane than the right, and thus the exposed part of the bronchus is longer on the left than the right side. From the upper side of the right bronchus a branch, which immediately divides into three, is given off for the upper lobe about three-quarters of an inch from the commencement and before entrance into the lung; and owing to this the right bronchus appears higher than the right pulmonary artery, while the left bronchus lies altogether behind the left artery. The branch for the upper lobe of the left lung comes off close to those for the lower lobe, the distance from the trachea to its origin being rather greater than to the breaking up of the right main bronchus into branches for the middle and lower lobes. Along to the origin of branches for the inferior lobe the main tubes have the same arrangement of cartilaginous rings as the trachea, and these are the parts properly termed the *bronchi.* But beyond this, in each lung a continuation may be distinguished prolonging the bronchus directly onwards, with the cartilages no longer in regular bars, but broken up into irregular pieces, as if composed of portions of successive bars partially united. This ends in a set of *elongated bronchial tubes* to the back part of the base, and gives off in its course others springing, some of them directly, some from short peduncles, and running a few of them inwards, but the greater number forwards and outwards. The elongated bronchial tubes have quadrate and angular plates of cartilage scattered irregularly in their walls. They branch dichotomously to a certain extent, but principally give off from their sides numerous small bronchioles devoid of cartilage. It is advisable to restrict the use of the term *bronchioles* to these and the still smaller tubes into which they divide.

The bronchi and their ramifications, including the elongated bronchial tubes, have microscopic structure similar to the trachea, stratified ciliated columnar epithelium, racemose glands, longitudinal elastic fibres and a transverse muscular coat; but when the cartilages become distributed all round, the muscular fibres are so also. After the cartilages have disappeared, the muscular coat is still found on the bronchioles, as are also the elastic fibres; while the epithelium becomes simple, and the surface of the mucous membrane continues longitudinally plicated. In the smallest bronchioles the muscular coat has disappeared, and the

simple ciliated columnar epithelium becomes exchanged for small non-ciliated squamous cells similar to those on the edges of the alveoli.

Vessels and nerves. The pulmonary artery is distributed to the lungs, supplying them with the dark blood which it is their office to purify from carbonic acid and replenish with oxygen. The branches of the pulmonary artery end altogether in the capillary network already described as surrounding the air-cells; and the purified blood is returned to the heart by the pulmonary veins, an upper and a lower from each lung. The superior pulmonary vein comes from the upper lobe, lying in front of the stems of artery and bronchial tube. The inferior pulmonary vein ascends on the inner side of the bronchus and its continuation; while the corresponding branch of the pulmonary artery descends external to them. The nutrition of the lungs is effected by means of the *bronchial arteries*, small vessels from one to three in number for each lung, arising irregularly from the aorta or intercostal arteries. They receive their name from being distributed mainly along by the course of the bronchial tubes, and as they supply the bronchial mucous membrane, as well as the other textures, their capillaries communicate with those of the pulmonary artery when the smaller tubes are reached. But they also furnish superficial branches by which the pleura gets a vascular supply independent of the lungs. The bronchial veins, which have likewise superficial and deep branches, fall into the azygos veins. The *lymphatics* of the lung are deep and superficial, and the superficial lymphatics form a network with larger meshes and vessels than are found on any other viscus. The *nerves*, the anterior and posterior pulmonary plexuses, are derived from the pneumogastric and sympathetic. They follow the bronchial tubes and have minute ganglia.

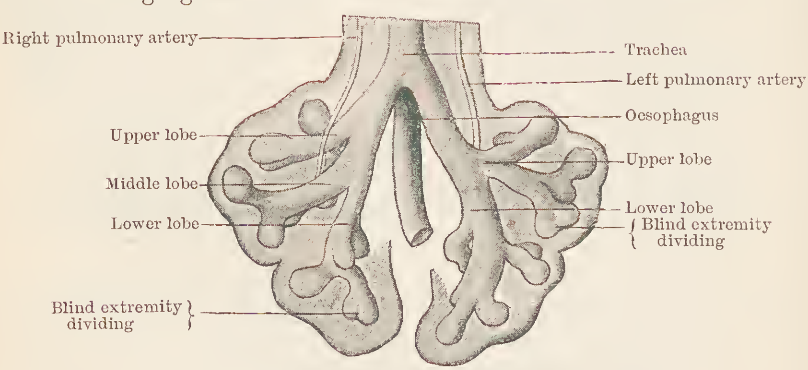


Fig. 587.—Embryonic Human Lungs. (Hertwig, after His.)

Development of respiratory organs. The deep groove which in early development is seen within the horse-shoe-elevation called the furcula (p. 99) deepens into an elongated tube of mesoblast with hypoblast within. This tube bifurcates, and already in an embryo two-thirds of an inch long, the lungs exist in the form of expansions outwards from the ends of

the bronchi; the left lung showing two, one for the upper and one for the lower lobe, while the right lung is larger and shows three, the beginnings of the three lobes of its adult condition. The right and left pulmonary arteries in the young embryo are also not symmetrically arranged; the right descends from its origin in a slightly more ventral position than the left, and passes on the ventral side of the neck of the upper lobe before entering the lung on the dorsal side of the others; while the left artery lies on the dorsal side of the necks of both lobes. Ramification rapidly proceeds; the extremities of the lobules always preserving a dilated appearance. It has been observed that in the fifth month the air-cells are only half the size of those found in the fourth month; the larger cells would therefore appear to become divided by septa.

Until birth the lungs, being unexpanded by entrance of air, occupy comparatively little space at the back part of the thorax, and have a specific gravity corresponding with that of similar textures in other parts; but after birth the expansion takes place immediately, and the air penetrates to the air-cells in a uniform manner depending on the mode in which the expanding force is applied.

The opening into the larynx soon exchanges its elongated slit-like form for a T shape, being transverse behind the epiglottis, and mesial between the arytenoid folds. The larynx of the male undergoes rapid enlargement at the time of puberty, and it is then that the pomum Adami becomes more prominent in the male than in the female. In connection with this the difference of pitch according to age and sex is to be noticed. Shortly it may be stated that the register of the voice in the child and adult, and in the male and female, depends on the length of the vocal cords, while the pitch of a particular note depends on the degree of tension to which they are subjected.

DUCTLESS GLANDS.

Under this old, but by no means indefensible designation, may be conveniently gathered various organs connected with elaboration or purification of the blood, viz., the spleen, the thyroid, the thymus and the suprarenal capsules, also certain arterial glomerular structures. To the same heterogeneous category belong the lymphatic glands, the closed follicles and the pituitary body; but these have been already described in the section on General Anatomy or with the parts to which they belong.

THE SPLEEN.

The spleen is attached by two folds of peritoneum, viz., the gastro-splenic omentum and the splenic ligament, to the great cul-de-sac of the stomach and to the diaphragm. It lies in the back part of the left hypochondrium and rests on the diaphragm and left kidney. When not

unduly enlarged it measures in the adult usually from four to five inches in length, from three to three and a half in breadth, and from one to one and a half in thickness; but it is subject to continual changes of dimensions, increasing in size for hours after food has been taken, and in disease it may be enormously enlarged.

The spleen has a convex surface or *dorsum* looking backwards and to the left, continuous behind with a rounded posterior margin, and in front with a thinner anterior margin interrupted usually with irregular notches. The remaining or internal surface, flattened behind where in contact with the left kidney, and concave in front where in apposition with the stomach, presents in the middle a vertical fissure, the *hilus*, at which the branches of the splenic artery enter and the tributaries of the splenic vein emerge between the anterior layer of the gastro-splenic omentum and the posterior layer of the splenic ligament, while the smaller sac of the peritoneum barely comes in contact with the spleen. Distinct supplementary splenules are sometimes found near the hilus both in man and other mammals.

Fig. 588.—Deep Surface of Spleen, showing the hilus, with the branches of the splenic artery entering.

Structure. Beneath its peritoneal coat and closely adherent to it, the spleen is surrounded by a strong *fibrous capsule* (*tunica propria*) closely bound down by continuity of its deepest fibres with a network of *trabeculae* running through the whole substance. On section the substance is seen to be of a dark venous hue, which, being covered by the fibrous capsule, gives a more or less dull purple colour to the surface; and on slight pressure there oozes from the section an abundance of dark *pulp*, which, when washed away, leaves displayed the fibrous trabeculae arranged in bars and imperfect septa round passages communicating one with another like those of a sponge. By repeated washing the whole pulp can be removed from the supporting framework of trabeculae, and the amount of elastic tissue in the trabeculae is sufficient to cause the framework to recover its original form when left for a short time in water or spirit. The pulp consists of corpuscles floating in a coloured fluid, and the corpuscles are of various kinds, namely, first, red blood-corpuscles; secondly, leucocytes in great number and variety, some of them similar to those found in the circulation, others much smaller, and some greatly larger, containing sometimes coloured substances, and sometimes undestroyed red blood-corpuscles (Stohr); thirdly, caudate or other branched corpuscles. Sections of spleen under the microscope exhibit also networks of branched corpuscles whose size diminishes while their branches elongate the further they are from the trabeculae, and pervade the pulp spaces with meshes of exceedingly fine threads. The

ramifications of the arteries and veins part company after a little, the small vessels quitting the trabeculae; and between the tunica media and tunica adventitia of the minute arteries there is a layer of retiform tissue which is swollen out in nodules by masses of minute nucleated corpuscles like the medullary substance of lymphatic glands or the contents of closed follicles, and contrasts with the pulp by absence of colour. These modules are called *Malpighian bodies.* They are not distinguishable in the healthy adult human spleen cut open, but in the spleens of children, and in pathological circumstances, and also in mammals other than man, they appear in

FIG. 589.—STRUCTURE OF SPLEEN. *tr*, Trabeculae; *ret*, reticulum; *M*1, Malpighian corpuscle with arteriole on one side; *M*2, another partially surrounding arteriole; *M*3, a third with arteriole in the centre; *M*4, a fourth without visible arteriole.

sections as semi-transparent grey spots, which have been likened to boiled sago grains. A Malpighian body may be pierced in the middle by the arteriole on which it is placed, but more frequently lies to one side. The branches of the splenic artery end in long and wide capillaries which do not form meshes as elsewhere, but open into the pulp-spaces, whence also the venous radicles take origin. This agrees with the fact that the serum of blood from the splenic vein has been found, like the splenic pulp, to be coloured with escaped haemoglobin. The spleen makes its appearance as a corpuscular mass in the second month of embryonic life.

THE THYMUS AND THE THYROID BODY.

These two structures have a closer connection with one another than with other ductless glands, being both of them originally developed like secreting glands from the pharynx, and losing their ducts in early embryonic life.

The thymus is an organ of early life. It has a colour and appearance resembling a salivary gland. It increases in absolute and proportionate

size till birth, preserves its proportionate size for a year or even two (Meckel), then begins to dwindle, and usually ceases to exist even vestigially in the adult, save perhaps in the form of a deposit of deep-coloured adipose tissue. It lies in the upper part of the anterior mediastinum of the thorax, and at birth forms a mesial mass reaching higher than the sternum and down over the great vessels and heart so as to conceal the auricles. It is most voluminous inferiorly, and superiorly is produced upwards on each side of the trachea as far as the thyroid body. By dissection it is easy to show that it consists throughout of a right and a left portion quite distinct one from the other, but closely in contact inferiorly, and not symmetrical. It is embedded in a sheath of connective tissue, and each

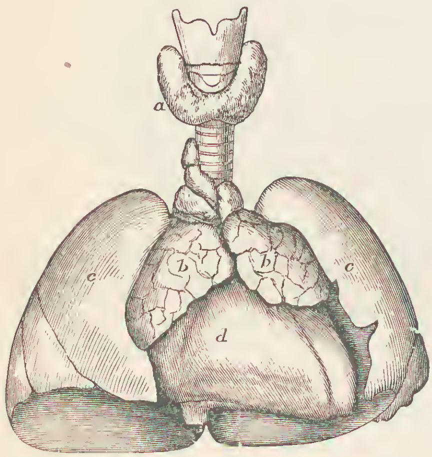


Fig. 590.—Windpipe and Thoracic Viscera of Foetus of Six Months. *a*, Thyroid body; *b*, *b*, thymus; *c*, *c*, unexpanded lungs; *d*, right ventricle of heart.

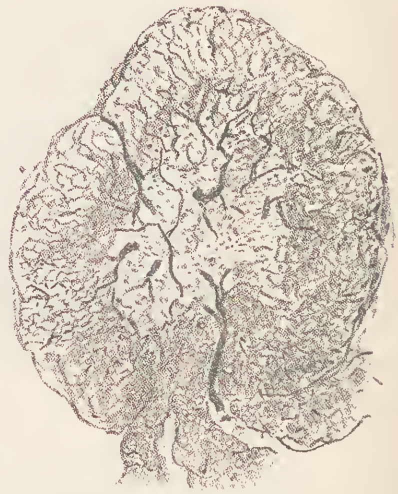


Fig. 591.—Section of Lobule of Thymus, from foetus of 8 months, with bloodvessels injected.

half can be dissected out into a number of lobules attached to a central cord or column, and consisting of smaller lobules. The lobules, surrounded by a dense vascular network sending into the interior bloodvessels whose capillaries fall short of the centre, contain a reticulum loaded with minute nucleated corpuscles. In the outer or *cortical* part, the corpuscles principally abound, while in the central or medullary part the reticulum is more evident; and it is this part which is continued into the central cord. In the medullary part a certain number of large corpuscles are found, some of them inclosed in concentric laminae (*corpuscles of Hassall*).

The thyroid body contrasts with the thymus in being firmer, of more definite form and less separable into lobules, in being of a dark purplish colour, in having very definite bloodvessels, and in continuing throughout life. It is larger in the female than the healthy adult male, and diminishes in the proportion which it bears to the whole body, from birth till adult age. It consists of two lateral lobes united by a narrow *isthmus*. The

lobes are covered by the sterno-hyoid and sterno-thyroid muscles, and reach up on the lower part of the sides of the thyroid cartilage and as low as the fifth or sixth ring of the trachea. The isthmus conceals the third tracheal ring completely, and more or less the second and fourth; and from it there sometimes ascends a *pyramidal process* or middle lobe, which may have muscular fibres descending to it, constituting a levator muscle. The thyroid body consists of multitudes of closed vesicles varying mostly from the sixtieth to the thirtieth of an inch in size, filled with glairy fluid, lined with a single layer of cubical epithelial cells, and surrounded with a distinct single layer of capillary bloodvessels. These vesicles are embedded in firm tissue, in which the vessels ramify. The arteries are the superior and inferior thyroid arteries, and the occasional lowest thyroid (*ima thyroidea*). The veins are the superior, middle and inferior thyroid. Of nerves to the proper structure of the thyroid body and thymus nothing is known.

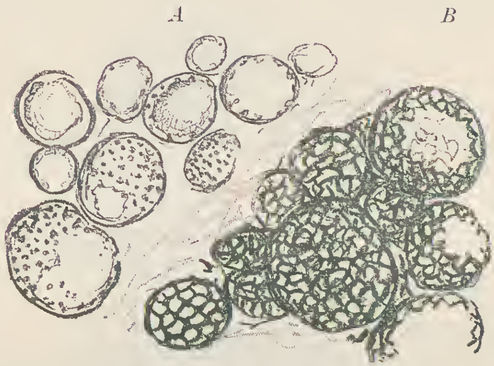


FIG. 592.—TEXTURE OF THYROID BODY. *A*, The vesicles lined with epithelium. *B*, Injection of capillaries showing a network round each vesicle.

Development of thymus and thyroid body. It will be observed from the statement made at p. 99 that those structures are closely related, in respect that they originate as glandular pouches from the visceral clefts, the thymus from the third clefts, the right and left lobes of the thyroid from the fourth clefts, and the mesial part of the thyroid from the ductus thyreo-glossus in the mesial plane opposite the third cleft. The close relation of both thyroid body and thymus to secreting glands is thus obvious; and in the thyroid body it would appear that the epithelial lining survives; while in the thymus it has disappeared altogether, and the structure which becomes developed corresponds with the retiform surroundings of the secreting pouches of an ordinary gland. In the foetus there are constantly found prolongations of both right and left parts of the thymus high up on the trachea, and it is probably from these that small bodies are derived described as *parathyroids*, an outer and an inner on each side, in contact with the lobes of the thyroid body.

THE SUPRARENAL CAPSULES.

The suprarenal bodies or capsules, or more properly the *adrenals* (Owen), are two flat bodies close above the kidneys, an inch and a half or more long, about an inch high, and diminishing in thickness from below upwards. The inferior edge of each fits over the convex upper end of the kidney, and an outer and an inner straight side slope upwards to a blunt apex. Its anterior surface is marked in the middle by a horizontal fissure, the *hilus*. It is of a dull ochreous colour, and is soft and easily torn, breaking open readily so as to lay bare a deeper brown and exceedingly soft texture in the interior, distinguished as the *medullary part*, while the surrounding substance is called the *cortical*. The right body is covered by the liver,

Fig. 593.—Right Suprarenal Capsule and Solar Plexus from right side. *a*, Kidney; *b*, at the outer end of the hilus of the suprarenal capsule. The vein is shown emerging from the hilus, and the nerves and arteries entering the circumference of the capsule. The capsular nerves are seen, most of them coming from the semilunar ganglion. *c*, Aorta and aortic plexus; *d*, renal artery and renal plexus; *e*, coeliac axis and coeliac plexus; *f*, superior mesenteric artery and plexus; *g*, inferior phrenic artery.

the left by the spleen and pancreas, and both lie on the crura of the diaphragm, external to the solar plexus. At their margins they receive numbers of nerves from the solar and renal plexuses, and numbers of small arteries coming irregularly from the phrenic, the aorta and the renal. The arteries break up into smaller branches on the surface and supply the cortical part with a capillary network, whence the venous radicles gather the blood into the medullary part, to escape from the hilus by larger branches which unite into a single trunk, ending on the right side in the inferior vena cava and on the left in the left renal vein. The cortical part examined microscopically exhibits a fibrous stroma continuous with a sheath round the whole organ, and ending on the deep side in a bounding layer separating it from

the medullary part. Within this stroma is inclosed the essential structure, consisting of nucleated corpuscles averaging $\frac{1}{1500}$th inch in diameter. These are arranged in the greater part of the depth in intercommunicating columns $\frac{1}{700}$th inch wide (*zona fasciculata*), continued superficially into irregular masses (*zona glomerulosa*), and at their deep extremities into a close network (*zona reticularis*). The medullary part receives the vessels and nerves which penetrate from the cortical structure, and while the vessels are gathered within it into venous trunks the nerves form a plexus. It also contains numbers of granular nucleated corpuscles connected one with another, but further observation is required to decide the detailed connections of the nerves and the relations of the medullary corpuscles to them.

The development of the suprarenal capsules is but imperfectly understood, but is alleged to be partly in connection with the solar plexus and partly from another origin. It is noteworthy that at an early period they are of a deep crimson tint very different from nervous structures, and only acquire their lighter colour afterwards.

ARTERIAL GLOMERULI.

Under this name may be mentioned some unimportant structures of small size, consisting mainly of convoluted and ramifying arterioles in minute clusters and of unknown history and function. They are: (1) the *intercarotid ganglion*, about quarter of an inch long, or broken into smaller nodules, between the external and internal carotid artery; (2) the coccygeal gland (Luschka), of the size of a lentil, between the tendons attached to the tip of the coccyx; and (3) some similar and still smaller structures appended to the coccygeal part of the middle sacral artery, found better developed in dogs (J. Arnold).

THE URINARY ORGANS.

The urinary organs consist of the kidneys, ureters, bladder and urethra; but the male urethra, being a passage common to the urinary and reproductive systems, will fall to be considered with the organs of generation.

THE KIDNEYS.

The kidneys are situated one on each side of the vertebral column, opposite the last dorsal and two or three upper lumbar vertebrae, but the right a little lower than the left. They are embedded in loose adipose tissue, and rest on the diaphragm and fascia of the quadratus lumborum behind them, and the psoas muscles internally, and are surmounted by the suprarenal capsules. They are pretty nearly on a level with the bodies of the last dorsal and two first lumbar vertebrae, and thus have the twelfth pair of ribs obliquely crossing them in their upper half behind. The right kidney is in contact anteriorly with peritoneum in its upper part, where

it impresses the under surface of the liver, and lower down is crossed by the duodenum and colon which are between it and the peritoneum. The left kidney is to a greater extent in contact with peritoneum, but is crossed by the descending colon.

The kidney weighs from four to six ounces, and may be as much as four inches long, two and a half broad, and one and a half thick. The surface is dark, smooth and even, sometimes with two or three curved indentations, the remaining traces of former lobulation. On its inner side, however, it presents a deep and limited depression, the *hilus*, in which is placed posteriorly the dilated commencement of the ureter turning downwards, and in front of it the renal artery, with the renal vein foremost of all, both artery and vein being higher than the ureter. As a general rule the kidney is flatter behind than in front, and the part below the hilus narrower and more elongated than the part above.

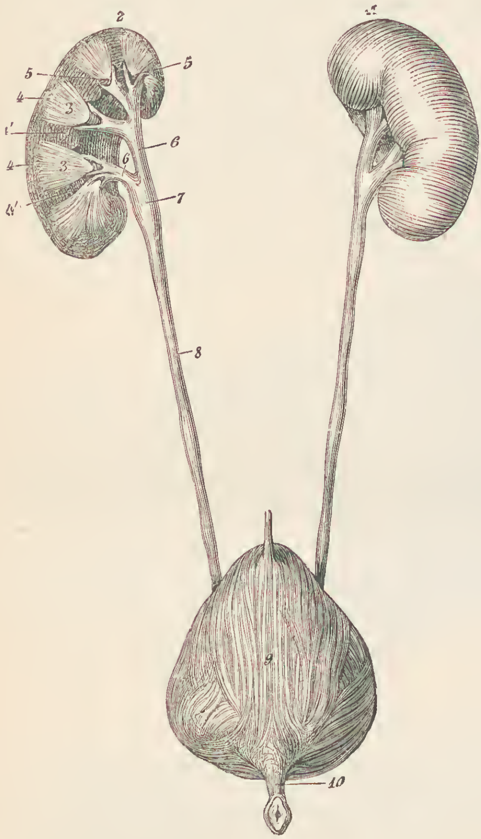


Fig. 594.—Female Urinary Apparatus. 1, Left kidney; 2, right kidney in section; 3, Malpighian pyramid; 4, cortex; 5, columnae Bertini; 6, layer calyx; 7, pelvis; 8, ureter; 9, bladder, surmounted by urachus; 10, urethra. (Luschka.)

Varieties. A kidney may receive one or more additional renal arteries entering it above or below the hilus. A kidney may be found in a position much lower than usual, even within the pelvis, and also at the other side of the middle line from its proper position, and receive its arterial supply from the nearest part of the aorta or one of its divisions. A number of instances of absence of one kidney are on record, and several cases of absence of both kidneys have been recorded in infants at birth. *Horseshoe kidney* is the name given to union of the two kidneys by their lower ends: it may be unsymmetrical.

Structure. The kidney is surrounded by a firm *fibrous capsule*, tolerably adherent, but easily separated in healthy specimens, and continuous with the tough connective tissue surrounding the structures which enter and

emerge at the hilus. The proper substance of the kidney consists of an outer or *cortical* part and an inner part or *medullary* between the cortical part and the *sinus* or cavity continuous with the hilus. The medullary substance is paler than the cortical and is arranged in masses averaging in number about a dozen, called *pyramids of Malpighi*, each with a rounded base continuous with the cortex and ending at its deep extremity in a free *papilla* which dips into the sinus. They present a distinct striation

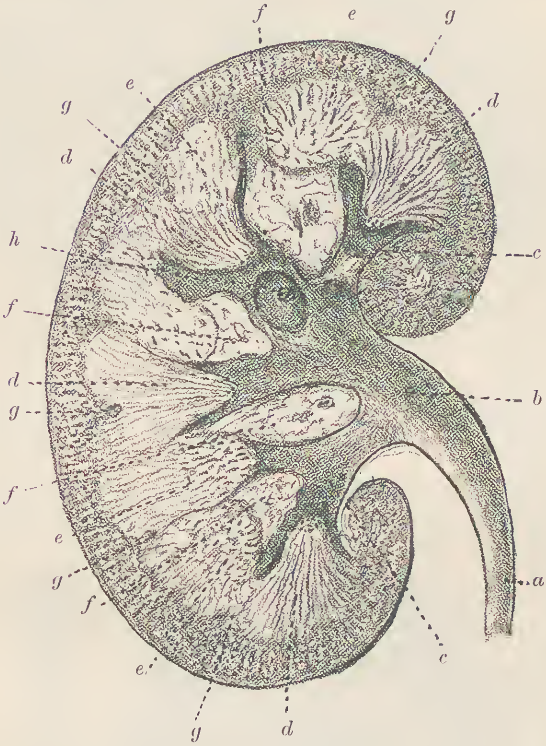


FIG. 595.—FRONTAL SECTION OF KIDNEY. *a*, Ureter; *b*, pelvis; *c*, *c*, calyces; *d*, *d*, *d*, *d*, Malpighian pyramids in section from base to apex, showing their papillae dipping free into calyces; *e*, *e*, *e*, *e*, oblique sections of pyramids; *f*, *f*, *f*, *f*, adipose tissue with cut bloodvessels; *g*, *g*, *g*, *g*, *g*, cut bloodvessels opposite septula; *h*, papilla looking out at the constricted end of a calyx. The uniformly granular stratum at the surface of the cortex is distinguished from the larger portion pervaded by medullary rays.

from papilla to base. The cortical substance is about quarter of an inch thick opposite the middle of each Malpighian pyramid and dips between the pyramids, forming *septula* (columns of Bertin). Along the plane of contact of the cortical and medullary parts a *zona intermedia* is distinguished by a slight displacement of striae due to bloodvessels coursing in this plane and sometimes by a tendency to venous congestion. Close to the surface the cortical substance is uniformly granular in its appearance to the naked eye, but further inwards the granular appearance is alternated with minute columns of striated material prolonged from the Malpighian pyramids and called *medullary* rays, while in the granular-looking part between each

pair of rays there may be seen on careful inspection, especially when the minute vessels have been injected or if a lens be used, scattered spherules, the *Malpighian corpuscles.*

FIG. 596.—CORTEX OF KIDNEY. Semi-diagrammatic. A, Tubules and Malpighian corpuscles round medullary rays (constituting with them two pyramids of Ferrein); D, afferent and efferent bloodvessels of Malpighian corpuscles, and the capillary networks.

The free papillae of the Malpighian pyramids are each embraced by a single division of the excretory tube. Such a dilatation, called a *calyx* or

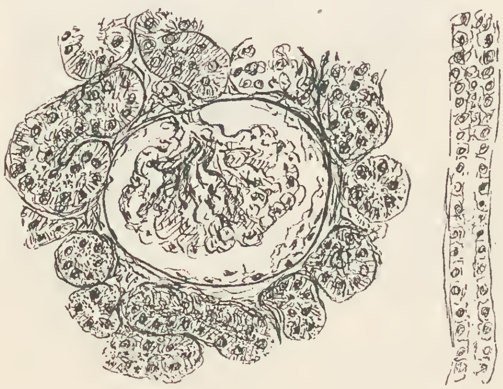


FIG. 597.—RENAL STRUCTURE HIGHLY MAGNIFIED. *A*, Malpighian corpuscle, showing glomerulus, epithelium and capsule, embedded in convoluted tubules with turbid striated epithelium; *B*, straight tubule with clear epithelium.

infundibulum, is attached at the base of the papilla to the renal substance, and narrows toward the summit, which it allows to look out by a small opening into one or other of two or three main divisions (larger calyces) of a dilated cavity, the *pelvis.* The pelvis may be as much as three-

quarters of an inch in vertical diameter, and as it escapes at the hilus turns downwards and narrows to the ureter.

The renal substance is made up of closely set tubuli uriniferi, which, together with the vessels supplying them, are bound firmly together by tissue so small in amount that the tubes seem in close contact; and though there are copious lymphatic channels between them, it is only by such means as maceration in muriatic acid that they can be separated to any considerable extent. To the pathologist this connective substance is important as the seat of scirrhosis.

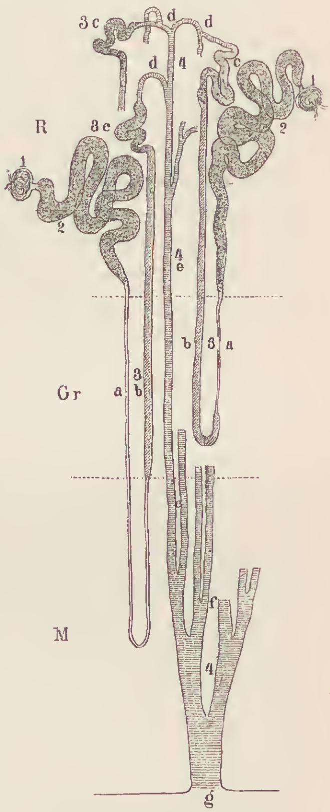


Fig. 598.—Diagram of Tubuli Uriniferi. *R*, Cortical part; *Gr*, intermediate zone; *M*, medullary part; 1, Malpighian corpuscles; 2, convoluted tubules; 3, Henle's loops; *a*, descending limb; *b*, reascending limb; *c*, intercalary tubule; 4, straight tubules; *d*, junction tubules; *e*, smaller collecting tubules; *f*, larger collecting tubules; *g*, papillary opening. (Schweiger-Seidel.)

The *tubuli uriniferi* begin in the cortical substance, each in a Malpighian corpuscle, and are in the first part of their course convoluted (*tubuli contorti*), in the latter part straight (*tubuli recti*), the convoluted part being confined to the cortex, and the straight part being principally in the medulla; but between the portions properly so-called are interposed two other parts, the *loop of Henle*, plunging with straight limbs far into the medulla, and the *intercalary tube* in the cortex.

The *Malpighian corpuscle* consists of a spherical wall called capsule of Bowman, from which on one side the convoluted tubule commences abruptly, while at an exactly opposite point two small bloodvessels, the *afferent* and the *efferent artery*, pierce it and are continuous with a bunch of small bloodvessels, the *glomerulus*, which fills in great measure its interior. In the glomerulus the afferent artery breaks up rapidly into convoluted branches which keep to the circumference of the globe and then turn towards the centre in loops to join together to form the efferent artery; and by this means the more the blood enters the glomerulus the more its circumference is expanded so as to leave room for the return current in the middle (Ludwig). A fine membrane, continuous with the capsule of Bowman, is reflected over the glomerulus from the neck at which the afferent and efferent arteries enter and emerge, and the opposed surfaces of this membrane and the capsule of Bowman are lined each with a single layer of fine squamous epithelium, the cells of the capsular layer larger than those of the glomerular layer.

The *tubuli contorti* begin by a somewhat constricted neck, one from each capsule of Bowman. They are so winding in their course as to give the granular appearance to the cortex. They are about $\frac{1}{400}$th inch or more in diameter and have a dense cubical epithelium, presenting a vertically striated or rod-like structure, with the limits of their corpuscles indistinct, while their nuclei are obscured by the turbidity of their protoplasm. Each convoluted tubule ends by turning inwards, forming what has been described as the *spiral tube*, and narrowing to the loop of Henle.

The loop of Henle is a constricted section of the uriniferous tubule, extending in a straight course far into the Malpighian pyramid and then abruptly turning back in an equally direct manner to the cortex. Its entering or descending limb is narrower than its emerging limb, being reduced to about $\frac{1}{2000}$th or $\frac{1}{1500}$th inch in diameter, while the emerging limb is more than twice as wide. In the entering limb the epithelium is squamous, in the emerging limb it is more nearly cubical.

The intercalary or *second convoluted tubule* is in its greater part somewhat similar in character to the first convoluted tubule, but its convolution is less and its cells less turbid. Towards its termination, however, it becomes narrower and its epithelium clear; and this part is what has been called the *junctional tube*, because it terminates the course of the simple tubule by opening into a collecting tubule. *The collecting tubules* in the outer part of the Malpighian pyramid are about $\frac{1}{600}$th inch in diameter, and each receives in the medullary ray junctional tubes one after another. As they near the papilla they join together and enlarge, until *papillary tubes* are formed as much as $\frac{1}{200}$th inch in diameter. They have clear cubical epithelium with distinct nuclei and distinct boundary lines between the individual corpuscles. The papillary tubes gather into groups which open into from ten to twenty depressions on the papilla, which may be seen with a lens.[1]

Each medullary ray receives the tubules which spring from the Malpighian corpuscles around and invest it superficially and on every side, and thus is constituted a simple lobule often spoken of as a *pyramid of Ferrein.*

Bloodvessels. The renal artery divides as it approaches the hilus into several branches, which, entering in front of the pelvis and passing in between its divisions, continue to bifurcate in the fat between the calyces and in the columns of Bertin, and end in numerous *arched* arteries in the zona intermedia, without, however, completing arches by anastomosis. From the convexities of these the *radiating* or *interlobular* arteries arise which are directed toward the surface between the pyramids of Ferrein,

[1] It ought to be explained that much of the microscopic structure of the kidney is by no means easy to verify, and in particular the sequence of the different parts of the tubules, though generally assented to as determined mainly by the researches of Ludwig and of Schweiger-Seidel, following up those of Henle, is difficult, and requires the examination of the kidneys of infants and of small animals.

and give off from their sides the *afferent* arteries, which proceed each to a Malpighian corpuscle without branching. Also branches are given to the fibrous capsule, which anastomose with twigs of the lumbar arteries. The afferent artery on entering the Malpighian corpuscle branches several times, and the resulting vessels of the glomerulus resemble capillaries in having simple walls; but their nuclei are very abundant, their walls are thicker than those of capillaries, and they are easily stained with carmine. The *efferent* vessel into which the blood from the glomerulus passes is sometimes termed a vein and sometimes an artery, but it has the structure of an artery, strong walls in which circular muscular fibres are a prominent feature. This efferent vessel breaks up again into capillaries, which among the convoluted tubules form a polygonal meshwork, and among the straight tubules run longitudinally with transverse communications. The vasa efferentia, emerging from the glomeruli nearest to the medullary part, differ from the others in turning towards the medullary part and dividing into straight vessels ending in capillaries which have been supposed to be the only sources of supply to that part; but though they are the principal they are not the only vessels, for *vasa recta* come also from the bases of the interlobular arteries and concave side of the arched arteries; and in contradistinction to these the branches of the efferent vessels are sometimes called *false vasa recta*. The venous blood is gathered from the cortex by *interlobular veins*, and some form on the surface little stars (stars of Verheyen); in the medullary part *straight veins* take their course, and both sets are gathered into *arched veins* which anastomose freely in the zona intermedia.

The lymphatics of the kidney consist of a sparse superficial set in the capsule and of a deep set opening into the valved vessels which emerge at the hilus. Within the renal substance lymphatics were first described by Ludwig and Zawarykin, who injected the intercommunicating spaces (1864). Ryndowsky (1872) found that the lymphatics were walled and lined with endothelium.

Development. After originating in connection with the Wolffian duct (p. 96), the ureter shows thickening at its extremity, the commencement of the kidney; and already in a foetus one and a half inches long from crown to coccyx, Malpighian corpuscles may be seen to form the greater part of its substance. A little later, when the kidney is only a sixth of an inch long, the Malpighian corpuscles are nearly as large as in the adult, and, together with other rounded structures which are folded dilatations of tubules and are evidently rudimentary capsules of Bowman, may, in vertical sections of the kidney, be seen ranged in continuous series folded backwards and forwards from surface to deep part. Convoluted tubes have been described as existing at this stage, but the convolutions are not those of the adult kidney; they present in their course the folded dilatations mentioned, placed more than one on a single tubule and filled with elongated columnar epithelium. The extremity of the ureter at an early

date shows dilated divisions. The loops of Henle appear early and have been seen in the human subject in the fourth month.

It has been pointed out that the kidney is derived from an elongated structure running the length of the body, and thus the mesonephros or Wolffian body is the permanent urinary gland of the lower vertebrates. It may be further mentioned that the mammalian kidney is considerably less diffuse than even that of the bird and is the only kidney confined in a fibrous capsule completely surrounding it. But to understand the development of the human kidney it is necessary also to know that the kidneys of mammals are not all alike. While some, like the rabbit and the kangaroo, gather their tubules to one papilla, or, like the sheep, to a central ridge, in others each kidney consists of a host of renules, separate as in the porpoise, or coherent as in the seal; and, much more commonly,

Fig. 599. — Suprarenal Capsule and Lobulated Kidney of Foetus of Six Months.

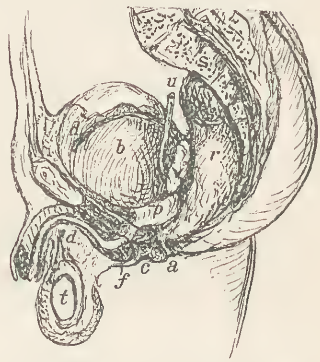


Fig. 600.—Male Bladder, Urethra and Rectum. *a*, Anus; *b*, bladder; *c*, central point of perineum; *d*, *d*, vas deferens cut across; *f*, bulb of corpus spongiosum; *r*, rectum; *s*, sacrum; *t*, left testis; *u*, ureter; *v*, vesicula seminalis.

there are lobulated kidneys like that of the ox in which a number of Malpighian pyramids occur, each with its portion of cortex forming a convexity on the surface. This lobulated condition is that which occurs in the human subject at birth, and becomes gradually concealed by the more abundant growth of the cortex. In some animals, as in the horse, the running together of lobes is still more complete than in man, the ureter ramifying backwards within a single mass of medullary tubules. Thus there are two kinds of smooth-surfaced kidneys among mammals, and the human kidney belongs to the compound kind and passes through an early smooth and a later lobulated stage. Lobules are noticed as early as in the tenth week of the embryo, and are most fully developed toward the end of foetal life.

THE URETERS.

The ureter is the duct conveying the urine from the kidney to the urinary bladder. It is from about fourteen to sixteen inches in length. Commencing at the pelvis of the kidney, which narrows as it emerges from the hilus, it curves downwards and is soon reduced to about a fifth of an inch in diameter. It ends in the lower part of the bladder, beginning to pierce the wall of that viscus about two inches from its fellow of the opposite side and an inch and a half from the base of the prostate. It is slightly dilated before entering the vesical coats, but becomes contracted in its succeeding part which courses gradually through them for more than half an inch to end in an oblique slit-like orifice pouting on the outflow of urine, but pressed shut by the contents of a distended bladder, so as to prevent regurgitation. In the abdomen the ureter lies behind the peritoneum, resting on the psoas muscle, and is crossed by the spermatic vessels and nerves; also, on the right side, by the mesentery of the lower end of the ileum, and, on the left, by the mesentery of the sigmoid flexure. It dips into the pelvis over the termination of the common iliac artery or the commencement of the external iliac, and as it courses forward is crossed in the male on its inner or peritoneal side by the vas deferens, while in the female it is in contact with the vagina before reaching the bladder.

Varieties. It may happen that the renal calyces, instead of opening into one pelvis, are gathered into two ureters (even three have been known to occur); and these may either join together or remain separate till close to the bladder.

Structure. The walls of the ureter present fibrous, muscular and mucous coats. The fibrous or outer coat consists of felted fibrous tissue. The muscular coat consists of a layer of circular fibres, and of deeper longitudinal fibres in the whole length of the duct; while, superficial to the circular fibres, longitudinal fibres are found in the lower third, but only in isolated bundles in the upper half (Toldt). The mucous membrane consists of a membrana propria and subjacent loose tissue, and is clothed with a stratified epithelium, whose superficial cells are flattened, while the deepest are smaller, rounded and oval, and intermediately placed are others of an elongated form, rounded at their superficial ends, and sending down pointed processes between the deeper cells. The vessels and nerves are from renal, vesical and mesenteric sources. The occurrence of lymphatic nodules and minute recesses, sometimes described as glands, seems to have been made out in the pelvis of the kidney and the upper part of the urethra.

THE URINARY BLADDER.

The bladder, as seen when artificially distended after death, is of an ovoid form, with the long axis mesial and the broader end below, and

measures from four to five and a half inches in length, and from three to four inches in width. During life it may be enlarged by habitually repeated distension, or diminished by continued irritability within the limits of health; while, by pathological retention of urine, it may be distended enormously. Conflicting statements, none of them sufficiently proved, have been made as to the comparative capacity of the male and female bladder; but, on an average, the female bladder is broader and more nearly spherical.

The bladder presents a *neck* or outlet, a *base* or *fundus* behind the neck, and, at the uppermost point of contact with the abdominal wall, a *summit* with a more or less distinct fibrous cord extending up from it to the umbilicus, which is the remains of the portion of the allantois termed the *urachus*, and sometimes shows vestiges of its original tubular condition. The outlet is fixed in position; it is separated from the posterior layer of the triangular ligament by about an inch of urethra, surrounded in the male by the prostate gland, and in the female by the thick muscular walls. From the outlet there extends, in the empty but uncontracted condition of the organ, an anterior wall resting against the pubic bones and reaching over the brim of the pelvis, and an inferior part, the *fundus*, curving backwards and receiving the ureters, in contact with the rectum in the male, and with the vagina in the female. The remaining and greater part of the posterior wall is laid over the base and anterior wall, in contact with them, and continuous with the anterior wall at lateral edges which meet at the summit. These edges disappear as the organ becomes rounded out, and then the surfaces pass gradually one into another. In like manner the edges disappear when the organ is drawn together in full contraction.

On each side of the bladder the obliterated hypogastric artery, as it courses upwards and inwards, runs for some distance in contact with it; and the reflections of peritoneum which reach the bladder at this part are called its *lateral false ligaments*, while that which descends to it between the arteries of opposite sides is called the *superior false ligament*, and those which in the male turn inwards to the lower part of its posterior surface below the contact of the arteries, are distinguished as the *posterior false ligaments*. In the female the posterior false ligaments can hardly be said to exist, the peritoneum being arrested, as it descends over the bladder, at the level of the cervix uteri; and so far as they do exist they are reflected from the sides of the uterus.

When the peritoneum is separated from the pelvic walls, the recto-vesical fascia is brought into view passing down to the neck and to the sides of the fundus, there to terminate by investing the bladder and, in the male, the prostate. The broad bands of fascia thus grasping the bladder, one on each side, are called its *lateral true ligaments*, and end in front in a pair of short stout bundles of fibres, the *anterior true ligaments*, one at each side of the symphysis, and separated by a mesial depression (p. 393).

The triangular portion of the bladder between the neck and the orifices of the ureters is called the *trigone*, and in the male rests on the rectum, so that it can be felt through the rectal wall immediately beyond the prostate, and can be punctured from the bowel without injury to the peritoneum. On each side of the trigone in the male is the vesicula seminalis, and internal to it the vas deferens, which descends on the side of the bladder, crossing between it and the ureter. In the male the peritoneum reaches down much nearer to the trigone than in the female, and the fundus projects further backwards, but is not, as sometimes described, lower in position in the erect posture than the outlet.

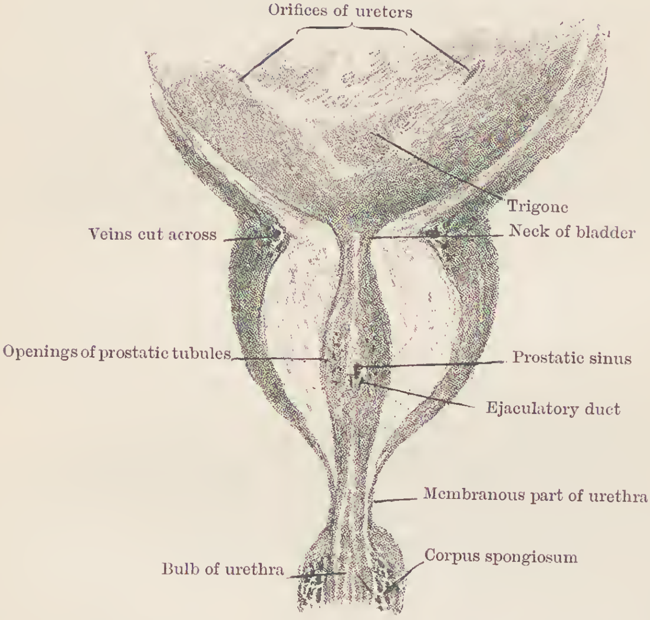


Fig. 601.—Base of Bladder, and the Prostatic and Membranous Parts of the Urethra, from the front.

The interior of the bladder has a smooth surface, which is thrown into folds when the muscular wall is contracted. *The trigone* as seen from the interior is an equilateral triangle with sides about an inch and a quarter long, the posterior angles formed by the oblique slit-like openings of the ureters and the anterior inferior angle by the outlet. Its floor presents a slight triradiate elevation caused by firm fibrous tissue subjacent to the mucous membrane, and connected with it so as to make it firmer and prevent its falling into rugae like the other parts. At the outlet of the bladder the mucous membrane is longitudinally corrugated, and in the male there is a slight elevation of the lower edge of the orifice, called *uvula vesicae*, due to the prostate gland which grasps the outlet, and liable when

the prostate is enlarged to be increased in size, and so offer obstruction to the entrance of instruments.

Structure. The walls of the bladder present, besides the partial investment of peritoneum and the connective tissue prolonged from the recto-vesical fascia, a muscular coat and a mucous membrane, separated one from the other by a *submucous coat* of loose areolar tissue, rich in elastic fibres, in which the arteries for the mucous membrane divide.

The muscular coat consists of fibres somewhat complexly arranged, yet easily resolvable into three layers closely connected one with another—a superficial, a deep longitudinal and an intervening circular layer. The *superficial longitudinal* fibres are arranged in two broad and strong bands, one in front and the other behind the neck, which both spread out on all sides as they ascend; the posterior band is traced downwards at the neck, between the bladder and at least the lateral lobes of the prostate, while the anterior band extends forwards on the surface of the prostatic part of the urethra, and some of its fibres reach the pubic bones in the substance of the anterior true ligaments. The lateral fibres of both bands spread out the most speedily, and are continued into the circular layer, while others arch round the summit, and a few, mesial in position, are continued to the urachus. The circular layer is the strongest, and at the neck is considerably thickened, forming a ring, the division of which by a special cut in lithotomy causes the outlet to expand. Higher up, its bundles cross in a reticulated fashion, which imparts its character to the interior in cases in which the muscular wall has been much exaggerated. The *deep longitudinal* fibres form a thin layer, regular below, scattered above.

The mucous membrane is similar to that of the ureters in so far as it is covered with a stratified squamous epithelium. The deepest cells are small; those superficial to them oval, caudate and spindle-shaped, while the superficial cells are granular and by no means as much flattened out as those of the epidermis. The superficial cells are clear at the surface and granular in their deeper part, in which are the nuclei. The nuclei are subject to direct or amitotic proliferation, sometimes as many as four being present in one large irregular plate-like corpuscle; and the granular portion of the corpuscle is pitted with deep depressions, into which are fitted elongated projections of the underlying corpuscles (Dogiel, 1890).

Vessels and nerves. The arteries are derived from the superior, middle and inferior vesical branches of the internal iliac. The veins fall into a copious plexus at the neck partly derived from the genitalia, and fall into the internal iliac veins. The nerves are derived from the inferior hypogastric plexuses of the sympathetic, and from the anterior divisions of the third and fourth sacral nerves. Small ganglia have been found on them, and their fibres would appear to have been traced into the epithelium.

Development. Derived originally from the proximal part of the allantois, the urinary bladder first communicates with the outside by its connection with the gut. A *cloaca* is formed by the junction of the allantois and the

bowel, and thereafter a septum separates a *uro-genital sinus* from the rectum. The subsequent stages by which the urinary part of this sinus becomes separated from the genital part do not seem to have been as yet followed in sufficient detail, but manifestly the trigone is the partition between them. At a later period the foetal bladder has the mucous membrane thrown into deep longitudinal corrugations, which cease suddenly at a transverse line and are replaced by a smooth surface at the level of the opening of the ureters.

THE REPRODUCTIVE ORGANS.

The organs of reproduction consist of structures which, in the two sexes, are differently developed but homologous, and are divisible into essential and accessory. The essential organs are the testes in the male and the ovaries in the female, and provide the living elements which unite within the impregnated ovum. The accessory organs are passages, glands and erectile organs, which in various ways facilitate the coming together of the products of ovary and testis, or in the female provide protection or nourishment for the embryo. In the male the urethra is in its greater part a genito-urinary passage, developed in connection with genital function; and in the female, although the urethra is urinary and homologous with the purely urinary commencement of the male urethra, yet it opens into the vestibule, which is thus a genito-urinary orifice.

MALE ORGANS.

I. The Testes, Scrotum and Seminal Ducts.

The testes or testicles, originally developed within the abdomen, where in non-mammalian vertebrates they remain permanently, have in man, as in the majority of mammals, the peculiarity that they descend before birth into the scrotum. They are placed at slightly different levels, the left usually the lower, so as to slide easily past one another when pressed on by the thighs. Each is hung by a *spermatic cord* consisting of the main duct termed *vas deferens* and the spermatic artery and spermatic vein, together with the spermatic plexus of sympathetic nerves and lymphatics, surrounded with coverings which are prolonged down over the testis itself and the special sac of serous membrane, *tunica vaginalis*, with which the testis is invested.

The coverings of the spermatic cord and testis are, in series beginning at the surface, the skin, subcutaneous tissue, dartos, intercolumnar fascia, cremaster muscle and cremasteric fascia, and the fascia termed in the upper part infundibuliform, and in the lower part fascia propria of Astley Cooper. The skin of the scrotum is thin, pigmented, highly extensible, furnished with scattered hairs provided with prominent sebaceous glands, presents a mesial raphe traceable back to the central point of the perineum and for-

ward to the penis, and in childhood and in the strong adult is thrown into transverse corrugations. The subcutaneous tissue is destitute of fat. The *dartos*, the highly muscular deep fascia, governs the corrugations of the skin. The scrotum is supplied with blood by the superficial perineal branch of the internal pudic artery and the superior and inferior pudic branches of the femoral, and with sensation by the ilio-inguinal nerve in front and the inferior pudendal branch of the small sciatic and two superficial perineal branches of the pudic nerve behind. Its lymphatics enter the oblique group of superficial inguinal glands.

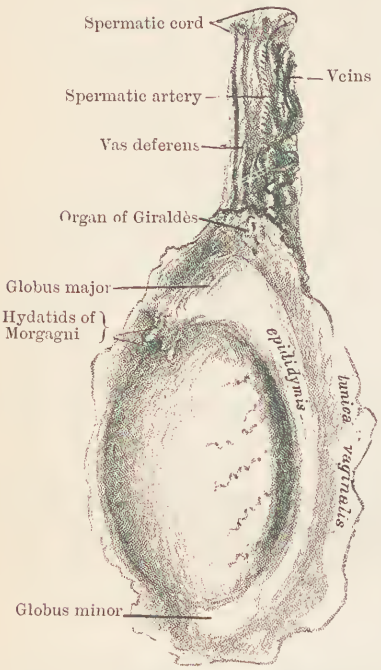


Fig. 602.—Left Testicle. Tunica vaginalis thrown open. Undulating branches of the spermatic artery are seen in the tunica albuginea covering the body of the testicle.

The testis is of oval form, approaching in size and shape to a pigeon's egg, but with the transverse breadth about a third narrower than the breadth from before backwards. The elements of the spermatic cord are continued to the back of the testis, where they are supported by a certain amount of unstriped muscular tissue, the vessels entering and emerging behind, and the vas deferens lying internal to them against the testis in its whole length. When the tunica vaginalis is laid open the form of the testis is laid bare. It is seen to be incased in a firm fibrous capsule, the *tunica albuginea*, over which the tunica vaginalis is firmly stretched, and to have above, below and to the outside of it, uninclosed by the tunica albuginea, an elongated structure which is called the epididymis; its swollen upper end above the testis proper being termed *caput epididymis* or *globus major*, the part alongside of the testis the *body* of the epididymis, and the part below the testis the *globus minor.* The globus major and minor are closely adherent to the tunica albuginea, while the intervening body of the epididymis, placed behind and to the outside, is separated from it by a pouch of tunica vaginalis, the *digital fossa*. Projecting from the lower and fore part of the globus major are one or more minute threadlike, clavate or pedunculated bodies called *hydatids of Morgagni*, vestiges probably of the upper end of an embryonic structure, the duct of Müller; and further up, where the tunica vaginalis is prolonged a little above the globus major, there may be found some less evident nodules beneath the membrane, which are known as *corps de Giraldès*, and are undoubtedly remains of the Wolffian body.

Structure. The whole secreting substance is inclosed within the tunica albuginea, which is a leathery white fibrous structure, resisting all efforts to stretch it by manipulation, but yielding before the continued pressure exercised in health, and enormously in orchitis. This is the better understood when it is observed that it is pierced behind by the numerous branches of the spermatic artery and veins, which course forwards in its substance and form by their finest twigs and capillaries an abundant network on its deep surface, the *tunica vasculosa* of Astley Cooper. The arteries also exhibit a fine undulation in their course forwards, permitting stretching without diminution of calibre. From behind, a fibrous septum projects a little forwards into the interior, the *corpus Highmorianum* or *mediastinum testis*; and from this mediastinum a number of slender cords and bloodvessels radiate forwards and to the sides to be attached all over the interior of the tunica albuginea.

FIG. 603.—DUCTS OF TESTIS. *a*, *a*, Tubuli seminiferi; *b*, *b*, vasa recta; *c*, rete; d, vasa efferentia; *e*, coni vasculosi; *f*, *f*, epididymis; *g*, vas aberrans; *h*, vas deferens.

FIG. 604.—SECTION OF LONGITUDINAL LOBES OF SEMINAL TUBULES. *a*, Tunica albuginea; *b*, tubuli seminiferi; *c*, tubuli recti; *d*, mediastinum.

The secreting substance, protected and supported by these fibrous structures, is soft, loosely adherent to its surroundings, and easily seen with the naked eye to consist of a mass of delicate threads, long portions of which can be partially unravelled and detached with ease, so slight is the cohesion of their convolutions. When the tunica albuginea is divided in front and reflected backwards, the contained mass presents a lobulated appearance; and about three or four hundred lobes can be separated pretty completely, all converging to the mediastinum, and consisting of *tubuli seminiferi* closely coiled. The

tubules, about a hundredth of an inch in diameter, can be uncoiled to lengths of as much as two feet. More than one enter into the formation of each lobule, and at the circumference the lobules are less easily separated than nearer to the mediastinum, because of connections between tubules of different lobules. Loops also occur within lobules, and it is difficult to make certain if blind extremities of tubules really occur, though the connective tissue supporting them is of the most delicate description. This connective tissue is remarkable in containing besides the ordinary connective-tissue-corpuscles, large rounded corpuscles, granular and sometimes pigmented, the nature of which has not been determined. The tubules exhibit throughout a fine uniform zig-zag which causes them when stretched to spring back, and are, besides this, thrown into laterally compressed folds. They are continued into *tubuli recti*.

The tubuli seminiferi have a strong membrana propria or basement membrane sometimes concentrically striated (Toldt), which like other basement membranes is alleged to consist of endothelial cells (Mihalkovics). Their interior exhibits in the condition of rest several layers of small nucleated corpuscles surrounding a lumen. But portions which are in a state of activity show a more complicated arrangement connected with the production of spermatozoa.

The spermatozoa constitute the essential product of the tubuli seminiferi, in the interior of which they are crowded closely together, as also in the epididymis and vas deferens, where they reach their maturity. They are firm structures, consisting of a head, neck and tail, and are in perpetual motion, moving head foremost with an eel-like movement of the tail as long as they retain their vitality, which in suitable fluids may be conserved for many hours. The head is about $\frac{1}{6000}$th inch long, pyriform, with the narrow end foremost, and is somewhat flattened, so as to seem broader in one position, narrower in another; it is succeeded by a cylindrical neck about half as long again, and the neck tapers into the slender tail, varying from $\frac{1}{400}$th to $\frac{1}{500}$th inch in length. A delicate membrane with a frilled free edge has over and over again been described as attached to one side of the tail of the spermatozoon of many animals and even of man, but there seems room to question if the appearances seen have been really due to a membrane.

Fig. 605.—Human Spermatozoa.

In tubuli seminiferi in which the formation of spermatozoa is going on, the corpuscles nearest to the membrana propria exhibit various stages of mitosis in their nuclei, and are, certain of them, at intervals round the tubule, greatly elongated into *spermatoblasts*, each presenting peripherally a base containing one distinct nucleus, and internally a clavate expansion which is supported on a constricted neck, and contains a number of nuclei. These spermatoblasts develop further, the clavate extremity becoming

digitate, each projection in connection with a nucleus; the nucleus throws out a tail, and, with a certain amount of protoplasm adherent to it, becomes free as a spermatozoon. Small portions of protoplasm have been observed sometimes surrounding the head like a cap, or adherent in a mass to the neck of a spermatozoon in later stages of its existence.

FIG. 606.—SECTION OF TUBULUS SEMINIFERUS OF RAT, showing genesis of spermatozoa. (Böhm and v. Davidoff after v. Ebner.)

The tubuli recti, into which the tubuli seminiferi pour their contents, are only about one-tenth of an inch in length, and are reduced to about one-fourth the diameter of the tubuli seminiferi. They are lined with a single layer of cubical epithelium, and open into the *rete testis*.

The rete testis, occupying the whole length of the mediastinum, is, as its name implies, a network of communicating passages. These have no membrana propria, and are lined with simple squamous epithelium; they vary in diameter, but are larger than the tubuli recti, and convey the secretion to the upper and back part of the tunica albuginea, when it falls into the *vasa efferentia*.

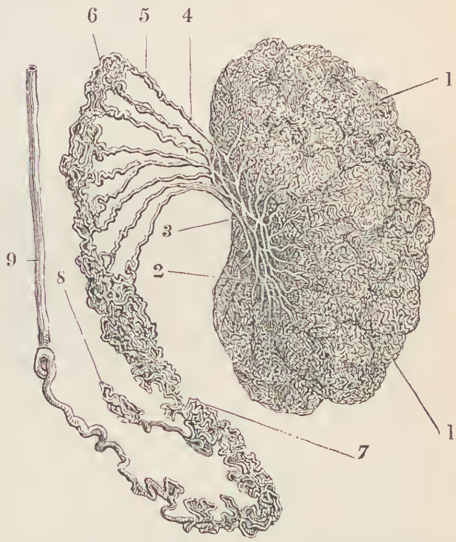


FIG. 607.—DUCTS OF TESTIS. 1, Tubuli seminiferi; 2, vasa recta; 3, rete; 4, vasa efferentia; 6, 7, epididymis; 8, vas aberrans; 9, vas deferens. (Beaunis, after Ecker.)

The vasa efferentia and *coni vasculosi*, from about ten to sixteen in number, are about a thirtieth of an inch in diameter. Escaping from the tunica albuginea, the *vasa efferentia* become each one almost immediately coiled up into a separate cone. These *coni vasculosi* are each over a third of an inch in length with the base at the further end about a tenth of an inch in diameter; but, in proportion as the cone gets wider, the tubule of which it is composed gets narrower till it is reduced to about a sixtieth of an inch, where it ends in the epididymis independent of its neighbours, the

whole series lying buried beneath the globus major of that duct. Like both epididymis and vas deferens, the vas efferentia and coni vasculosi have ciliated columnar epithelium and membrana propria, with muscular fibres outside.

The epididymis, when dissected out, is found to consist of one elongated tube about a sixtieth of an inch in diameter in the globus major, and diminishing to a third of that diameter as it is followed to the globus minor, in which it again enlarges, prior to being continued into the vas deferens. It is three times folded on itself, first into uniform close-set semicircular waves, then backwards and forwards, and lastly in larger backward and forward folds, so as to produce lobes separated from others by loose connective tissue. It begins in a blind extremity, and receives the coni vasculosi in series at short intervals. The whole tube is indubitably twelve feet at least in length, and has even been estimated at twenty feet or more. The wall presents beneath the columnar epithelial cells a layer of rounded nuclei, and round the membrana propria a thin stratum of muscular fibres.

The vas aberrans (Haller) is a tubule coiled on itself of about the same diameter as the epididymis, and opening into that duct where it is continued into the vas deferens. It may reach to eight inches or more in length, but may be absent, and is said sometimes to be unconnected with the epididymis. It lies in the concavity between epididymis and vas deferens, and would appear to be a vestigial structure, resulting from processes in development not yet sufficiently studied.

The vas deferens is continuous with the epididymis where that duct has reached the lower end of the globus minor. It turns upwards behind the testicle, internal to the spermatic vessels and nerves, enlarging rapidly while in contact with the globus minor, and getting less tortuous till it reaches more than half way up the back of the testicle. It there becomes straight and has already acquired a uniform cylindrical shape with dense walls of such thickness and firmness as to make it feel like whip cord. It extends upwards in the spermatic cord, behind the spermatic vessels and nerves, to the external abdominal ring, traverses along with them the inguinal canal, and, on reaching the internal inguinal ring, quits them and, turning down over the external iliac vessels, enters the pelvis and sweeps downwards in contact with the bladder. It crosses backwards between the bladder and ureter to reach the posterior edge of the base of the prostate gland, where it terminates by joining with the outlet of the vesicula seminalis to form the *ejaculatory duct*. In this course it is about sixteen to twenty inches long. In the last two inches, where it is internal to the ureter, it becomes dilated and sacculated, forming a sort of elongated ampulla before ultimately narrowing again at its termination. The vas deferens has an outer coat of loose fibrous tissue, and a strong muscular wall in which three layers are distinguished, an outer and an inner of longitudinal fibres, and an intervening layer of circular fibres,

which is as thick as the two other layers put together. The mucous membrane exhibits mostly three longitudinal rugae, and has elongated non-ciliated columnar epithelium with elongated nuclei resting on a layer with spherical nuclei; but the sacculated terminal part has some special peculiarities, being thrown into shallow recesses lined with cubical epitheliun. The vas deferens is supplied by a special branch of the inferior vesical artery, which runs its whole length as far as the epididymis; and its nerves are derived from the inferior hypogastric plexus.

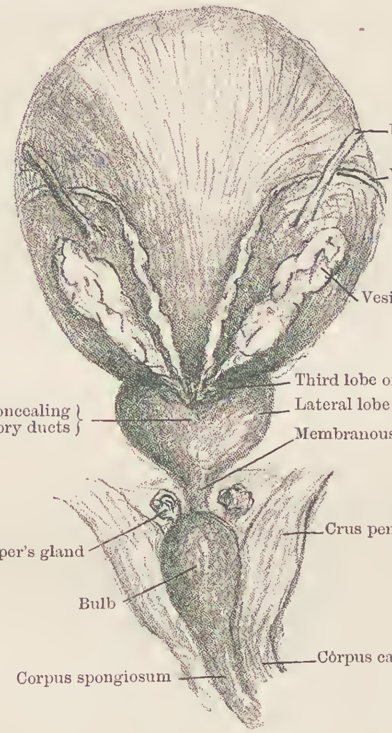


FIG. 608.—BLADDER, PROSTATE AND BULB, from behind.

The vesiculae seminales are sacculated pouches folded together so as to form structures less than two inches in length, and about two-thirds of an inch wide, lying on each side against the bladder, immediately external to the vas deferens. The pouch may be as much as four or five inches long when unfolded, and has saccules of unequal length, some of which may even be branched. It is narrow at the outlet, but in its course its mucous membrane may be about quarter of an inch broad when slit open. Like the vas deferens, it is lined with non-ciliated columnar epithelium, and has circular muscular fibres with longitudinal bundles superficial and subjacent to them. The surface of the mucous membrane is reticulated like that of the gall-bladder, but more finely. Muscular fibres have been found

crossing the folds, and even joining the vesiculae seminales of opposite sides.

The ejaculatory ducts, one on each side, are formed each by the union of the vesicula seminalis and vas deferens. They are not much more than half an inch in length, extending from the base of the prostate, between the lateral and middle lobes to open into the floor of the urethra, slightly in front and to one side of the sinus pocularis. Each narrows from its commencement to its termination, where it is only wide enough to admit a fine bristle. Its walls are thinner than those of the vas deferens and vesicula seminalis, but are supported by the prostatic structures.

II. The Prostate, Penis and Urethra.

Firmly united to the neck of the bladder in the male there is a firm and thick mass, the prostate gland; and it is in the part of its course within the prostate that the urethra receives the openings of the ejaculatory ducts, and becomes a common genito-urinary passage. Half-an-inch beyond the prostate, the urethra emerges outside the pelvis, having pierced the triangular ligament, and is surrounded by an erectile structure, the corpus spongiosum, which, together with the two corpora cavernosa, the glans and integuments, enters into the structure of the penis.

The prostate gland is a structure aptly enough compared in shape and size to a chestnut. Its base surrounds the outlet of the bladder; it is elongated and convex behind and comparatively short in front, and owes its name to the erroneous conceptions formerly prevalent as to the position of the pelvis in the erect posture, which led it to be supposed that the prostate lay in front of the bladder, whereas in the erect posture it really lies below it. It rests behind on the rectum, and can be felt through the rectal wall above the internal sphincter, and below and in front of the trigone of the bladder. It is supported by both anterior and lateral true ligaments of the bladder, formed by the recto-vesical fascia (p. 393), and in front of these is separated from the posterior layer of the triangular ligament or subpubic fascia by the anterior fibres of the levatores ani. The recto-vesical fascia invests it with a strong fibrous capsule, and where the fibres of this capsule extend to the bladder, an angular interval is left round the base, which lithotomists avoid, because the looseness of the tissue contained in it is apt to lead to urinary infiltration, and the prostatic plexus of veins is liable to be specially developed at the base. The prostate has a bilobate appearance as seen from behind, and when the ejaculatory ducts are followed into its substance the greater part of it is found to be in continuity with these *lateral lobes*; but between the structure through which the ejaculatory ducts pass and the bladder there is left a mesial third lobe.

Structure. This structure is partly muscular and partly glandular. The glands open by about twenty orifices into the floor of the urethra. They are elongated branching tubules with sparse and small acini at their extremities,

and both ducts and acini lined with columnar epithelium. They are absent, or nearly so, from in front of the urethra. The muscular substance is wrapped round about at different depths; the deepest fibres are continuous with the circular fibres already described at the neck of the bladder, and superficial to them are others decussating with different degrees of obliquity on the urethra and continued into the vesical wall. On section of the prostate, fibres are seen embracing the urethra, others at the circumference, and a third set extending in the intervening depth between the glands. The arrangement of the glandular part of the third lobe between the urethra in front and muscular and white-fibrous tissue behind is of importance from a surgical point of view, inasmuch as the prostate is prone to enlargement in later life, and the enlarged glandular part of the third lobe, being supported behind by muscle and thickened fibrous tissue, tends to press forwards and make an increased convexity in the floor of the urethra, which offers resistance to the direct passage of instruments and has to be carefully humoured.

The prostate is supplied principally by the inferior vesical arteries. The plexus of veins around it is not so much derived from branches bringing blood from its substance as from the veins of the penis; the nerves are derived from the inferior hypogastric plexuses, and are said to present nerve-cells in their course, and also Pacinian bodies.

The penis consists fundamentally of two erectile bodies called corpora cavernosa, but in mammals is complicated by the prolongation of the urethra

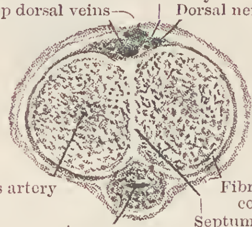


Fig. 609.—Body of Penis in Transverse Section.

along its under surface, surrounded by a mesial erectile body, the corpus spongiosum, in connection with the fore part of which is the glans, an erectile structure expanding over the extremities of the corpora cavernosa.

The corpora cavernosa are cylindrical structures consisting of spongy erectile tissue surrounded by a strong fibrous sheath. They arise separately, attached, one on each side, to the margins of the pubic arch, and taper backwards as far as the front of the ischial tuberosity, with the ischio-cavernosi or erectores penis muscles covering them. They become united opposite the inferior margin of the symphysis so as to leave only a single fibrous septum between the two columns of erectile tissue, and constitute with the corpus spongiosum the *body* of the penis, while the separate portions

are called the *crura*. In front they terminate under cover of the closely adherent glans in two blunt extremities like the tips of two fingers held together. The septum is strongest towards the root, and consists of bundles passing directly between the dorsal and lower surfaces with narrow clefts alleged to afford communication between the right and left corpora cavernosa. The circumferent fibrous walls form a thick, white and smooth covering, with its bundles in large part longitudinally arranged, and containing a considerable quantity of elastic fibres. From the deep surface of the walls, rounded and flattened trabeculae extend into the interior of each corpus cavernosum, forming the supporting part of its structure, while the cavities between them intercommunicate freely and are blood-sinuses. The cavernous artery from the internal pudic trunk passes right up through the middle of each cavernous body, and the dorsal artery of the penis gives branches as well. The arterial twigs ramify in the trabeculae, and are continued into capillaries which open into the sinuses. Some of the small arteries project sinuously from the walls of the sinuses in a curling fashion, and constitute the *helicine arteries* (of J. Müller). The blood escapes by veins falling into the internal pudic and the dorsal vein of the penis.

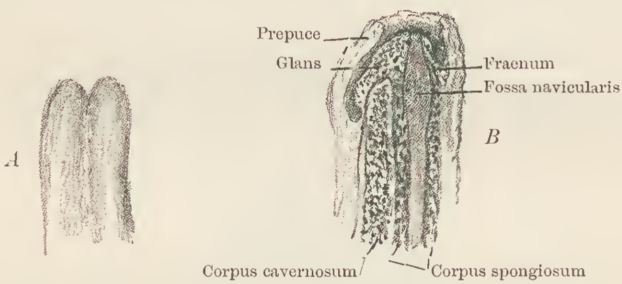


FIG. 610.—TERMINAL PARTS OF PENIS. *A*, Corpora cavernosa dissected away from the glans and corpus cavernosum. *B*, Longitudinal section.

The corpus spongiosum is an erectile structure surrounding the urethra after its escape from the pelvis. It begins between the crura penis on the surface of the triangular ligament, and occupies the groove on the under surface of the corpora cavernosa as far as the glans, with which it is continuous. It is dilated at its commencement, where it is covered by the acceleratores urinae or bulbo-cavernosi muscles, and reaches back to their origin from the central point of the perineum. This part is called the *bulb*, and extends nearly half an inch further back in the perineum than the urethra which it surrounds. The average thickness of the erectile covering given to the urethra by the corpus spongiosum is about the eighth of an inch. Both the erectile tissue and the sheath encircling it are much weaker than those of the corpora cavernosa. The corpus spongiosum receives its arterial supply from the artery of the bulb, given off by the internal pudic, and from a smaller subsequent branch of the same trunk.

The glans penis presents at its summit the linearly shaped urethral orifice, but fails to surround it at its inferior angle, from which a mere fibrous union, the *septum*, extends back half an inch, uniting the urethra with the fibrous sheath of the corpus spongiosum. From each side of the septum the margin of the glans retreats from the urethral orifice in its course round to the dorsum, at the same time that it becomes more overhanging and constitutes the *corona glandis*, while the constriction beneath it is called the *cervix*. The erectile tissue of the glans is continuous with that of the corpus spongiosum, but has claim to be considered as a separate development, being fully developed in the congenital deformity termed epispadias, in which the urethra is an open groove placed above the corpora cavernosa. Moreover, its trabecular structure is stronger, and its lacunae have been found to have more the character of dilated and convoluted veins. Its fibrous covering is the cutis vera of the delicate integument which constitutes its free surface. The papillae of the surface of the glans are close-set and rounded, scarcely longer than broad, except at the corona; and both in the papillae and more deeply there are situated nerve-terminations, distinguished by Krause as more complex than end-bulbs and called *genital corpuscles*, in which recently there have been discovered convoluted networks of nerve-fibres marvellously complex (Dogiel, 1893).

The integument of the penis, with the exception of that entering into the structure of the glans, is loose, and has a raphe continued forwards from the scrotum. It is thin and free from hairs and fat. The folded part which covers the glans is called the *prepuce* or foreskin, and where it is attached to the septum of the glans it forms a prominent *fraenum*. Around the corona, on the cervix and on the inner layer of the prepuce, there are sebaceous glands, though no hairs are present.[1]

The male urethra may be counted as about nine inches long, and consists of three parts, prostatic, membranous and spongy. *The prostatic part*, from an inch to an inch and a half in length, is narrower at its commencement at the outlet of the bladder and at its termination in the membranous part than in the middle where it has its convex *floor* or posterior surface in contact with its anterior surface. From the uvula vesicae at the orifice of the bladder a prominent line runs along the floor to the middle of the prostatic part and is there continued into a little rounded eminence, the *colliculus seminalis*, *verumontanum* or *caput gallinaginis*, then resumes the linear form and ends by bifurcating in front. In the depression at each side of the colliculus are the openings of the prostatic glands, while connected with the colliculus itself are three openings. In its fore part in the middle line is an orifice which admits the end of a probe and leads into a blind pouch sometimes as much as half an inch long, the *sinus pocularis* (*uterus masculinus* or *Weber's pouch*), corresponding

[1] On the subject of the glands in this situation (commonly called Tyson's), consult Henle, *Anat. d. Menschen*, *Eingeweidelehre*, p. 418.

not only with the uterus of the female but with the vagina also (Banks, 1864); and, close to the sinus pocularis but somewhat further forward, one on each side, are situated the openings of the ejaculatory ducts. A certain slight amount of erectile tissue, prolonged back in the floor of the urethra from the bulb, increases in amount in the colliculus, and must serve when gorged to obstruct for the moment the exit from the bladder.

The membranous part of the urethra is half an inch long, extending from the apex of the prostate to the entrance into the bulb, and lies between the deep and superficial layers of the subpubic fascia, surrounded by the constrictor urethrae muscle. It is the narrowest part of the urethra, with the exception of the orifice.[1]

The spongy part of the urethra extends from the opening in the triangular ligament to the outlet. At its commencement in the bulbous portion of the corpus spongiosum it is slightly dilated and somewhat rugose longitudinally; and when the constrictor urethrae is contracted, an instrument can be pushed a little further back in the perineum than the opening in the triangular ligament, but if held gently against the easily felt opening, it will pass in of its own accord when the constrictor relaxes. At its entrance into the bulb, the urethra changes its course from a downward to a forward direction, so that a curved instrument introduced so far with the handle close to the abdomen moves away from the abdominal wall on entering the membranous part. In front of the bulb, the diameter of the urethra is very slightly diminished and continues unchanged till about half an inch from the orifice, where there is a distinct dilatation, the *fossa navicularis*, bounded in front by the more constricted slitlike orifice. While surrounded by the corpus spongiosum the tube has the upper and lower walls in contact; but near the outlet it is compressed from side to side by the glans, so as to present mesial contact of two lateral walls. A variable number of blind depressions called *lacunae*, with their mouths directed forwards and capable of intangling the point of an instrument, are found principally on the floor, near the bulb; a large one found very frequently on the upper surface of the fossa navicularis is known as the *lacuna magna* (also valvule of Guèrin).

The mucous membrane of the urethra presents columnar epithelium on a smooth surface, except within the glans, where, as on the exposed part, there is a papillary surface covered with stratified squamous epithelium. The proper substance of the mucous membrane is firm, and contains a large amount of elastic tissue longitudinally arranged. It has a copious capillary network and venous plexus. The prostatic part of the urethra is in contact with the muscular tissue of the prostate; the membranous part has a strong

[1] This part of the urethra is well known to be specially liable to injury in consequence of falls on the pelvis, even when there is no fracture of the bones. There can be no doubt that the explanation once offered by Goodsir in answer to an inquiry by Syme, and accepted by the latter, is correct, namely, that the weight of the body propelling downwards the base of the sacrum unduly wedges upwards the part nearer the coccyx, so as to force open the arch of the pubis and tear the structures contained in it.

covering of circularly arranged unstriped muscular fibres, in contact with the striped fibres of the constrictor urethra, and is said to have longitudinal fibres embraced by them; the circular fibres are continued in the bulb, but get fewer further forwards, and ultimately disappear.

Mucous glands, lined with columnar or cubical epithelium and with ducts directed forwards, are found over the whole urethra, as far as the squamously lined part at the outlet. Some are simple, while others are racemose and have longer ducts, and are situated in the submucous tissue, and are known as glands of Littré. Lastly, *Cowper's glands* are a pair of firm racemose glands about the size of small peas, with unstriped muscular fibres around them, situated on the surface of the constrictor urethrae and under cover of the deep transversus perinaei muscle. Their ducts, an inch or more in length, are directed forwards beneath the mucous membrane, and terminate separately in the floor of the bulbous portion of the urethra.

FEMALE ORGANS.

I. The Ovaries, Uterus and Fallopian Tubes.

The ovaries are a pair of firm, white fibrous bodies, which in the young adult measure about an inch and a quarter in length, three-quarters of an inch in breadth, and three-eighths in thickness, and have a smooth

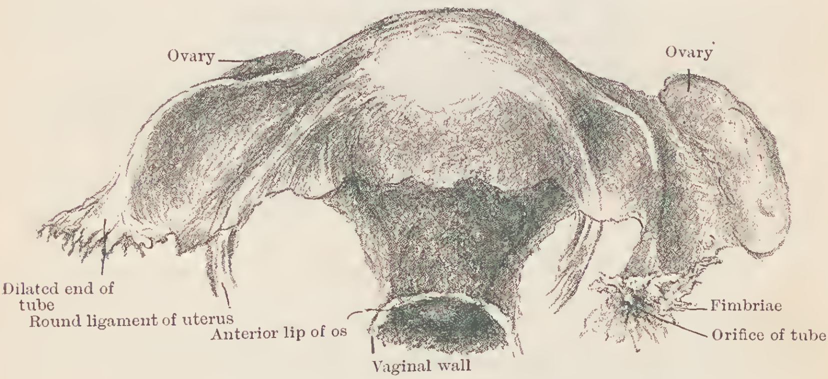


Fig. 611.—Uterus, Ovaries and Fallopian Tubes, from the front.

surface covered with peritoneum. But in consequence of the ova escaping at the monthly molimen, by laceration of the peritoneal surface, cicatrices gradually accumulate; and the ovaries in elderly subjects are not only shrivelled but marked with indentations and linear depressions. They are attached each by the anterior border to a fold of peritoneum, *broad or suspensory ligament of the ovary*, projecting slightly backwards from the broad ligament of the uterus, below and behind the Fallopian tube; and within this fold a fibrous band, the *round ligament of the ovary* (*ovarian ligament* of

some authors) unites each to the corresponding cornu uteri. The exact position of the ovary, when its ligaments remain unaltered, may be said to be determined by the position of the uterus and by the entrance of the round ligament of the uterus into the inguinal canal. When the uterus is neither pregnant nor displaced, the ovary rests in the depression between the external and internal iliac arteries, and the end furthest from the uterus is superior and posterior to the other. Along the attached border it presents a linear depression or *hilus*, from which the vessels and nerves can be traced spreading out in the interior.

Within the ovary, tortuous vessels abound, some only for a depth of from a sixteenth to a twenty-fifth of an inch below the peritoneum, which is distinguished as the *cortex*, while the rest is termed the *medulla*. The stroma of the ovary consists of a richly corpuscular fibrous tissue, in which the great majority of the corpuscles are spindle-shaped, and contains a notable number

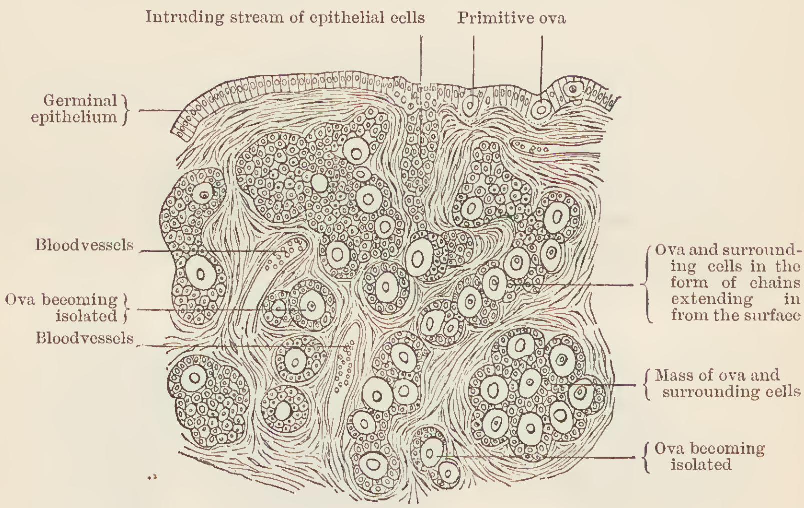


Fig. 612.—Section of Ovary of Child at Birth. (Hertwig, after Waldeyer.)

of elastic fibres. The medulla abounds in winding arteries and veins, and contains a number of spindle-shaped corpuscles, larger than those of the cortex and considered by some as muscular, and it has also stellate corpuscles, held by many as nervous. The cortex or *ovigenous stratum* has its fibres more uniformly felted and more nearly parallel to the peritoneum, and is but slightly vascular; it is the part in which the ova are developed, and when examined with the microscope is seen from foetal life up to the young adult condition to abound in multitudes of minute ova in different stages of development. Scattered about in the cortex in active ovaries there are always visible a few clear cysts, the larger members of a vast number of follicles, each surrounding an ovum, the *Graafian vesicles*. The smaller of those visible encroach on the medulla, and the larger occupy the

whole thickness of the cortex, showing themselves at the peritoneal surface, and reaching to a sixth of an inch in diameter. Sometimes also there is seen a yellow body, *corpus luteum*, or a large Graafian vesicle filled with blood-clot, or a corpus luteum with blood-clot in the centre; the explanation being that one or more Graafian vesicles burst at each menstrual period, liberating the contained ovum and becoming filled with blood, and that, as the clot disappears, a yellow structure is developed in the surrounding wall, increasing for a number of days and afterwards disappearing, except when pregnancy takes place, in which case it becomes larger and persists for a number of months.

The ovum is a spherical body, measuring in a full-sized Graafian vesicle in the human subject $\frac{1}{120}$th inch in diameter, and presents a clear wall, the *zona pellucida*, surrounding the granular *vitellus* or yelk, in the interior of which is a clear spherical *germinal vesicle* about $\frac{1}{800}$th inch in diameter, inclined toward the superficial side and containing a granular body, the *germinal spot*. Around the ovum is a heap of small corpuscles, the *discus proligerus*, which adheres to the inside of the Graafian vesicle at the part nearest to the peritoneum, and is continuous with corpuscles of the same kind lining the whole vesicle, the *tunica granulosa*. In the wall of the Graafian vesicle two layers are distinguished, an outer or fibrous layer continuous with the stroma, and an inner or vascular layer named the *ovisac*. It is in the ovisac that the development of cells loaded with oil globules, giving character to the corpus luteum, takes place after bursting of the vesicle. In smaller Graafian vesicles than those visible to the naked eye, the ovum occupies the middle of the Graafian vesicle and the germinal vesicle the middle of the ovum, and one mass of corpuscles fills the cavity of the Graafian vesicle around the ovum. The Graafian vesicles get smaller toward the surface of the cortex by diminution of the number of lining corpuscles much more than by diminution of the ovum, and the smallest ova have only a few corpuscles round them. The peritoneum on the surface of the ovary is covered not with the delicate epithelium or endothelium found on the peritoneum elsewhere, but with minute columnar epithelium, the remaining portion of the germinal epithelium (p. 97) from which the ova and probably the cells around them are derived, most of them in foetal life. Thus it appears that the ova, beginning on the peritoneal surface as elements of the germinal epithelium, travel in through the stroma of the ovary till they reach the deep limit of the cortex, where the vascularity is favourable to the development of the ovisac, and that afterwards the expansion of the Graafian vesicle

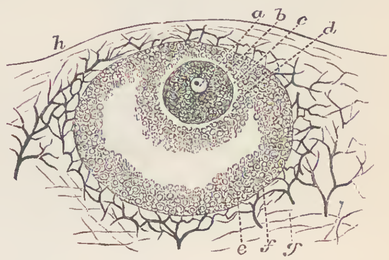


FIG. 613.—HUMAN OVUM within Graafian vesicle, $\frac{30}{1}$. *a*, Germinal vesicle and spot; *b*, vitellus or yelk; *c*, zona pellucida; *d*, discus proligerus; *e*, membrana granulosa; *f*, vascular wall of ovisac; *g*, stroma of ovary; *h*, surface of ovary.

with fluid causes it to follow the same law as governs other collections of fluid, and push aside the textures on the side on which there is least resistance.[1]

The uterus, or womb, is a hollow organ reaching above to the brim of the pelvis, continuous above on each side with the Fallopian tubes, and opening below into the vagina. It is a pyriform body, with thick muscular walls which give it the firmness of a solid structure, and is in the adult and unimpregnated condition about three inches long, two inches broad, and one inch thick at the upper and broadest part. A slight concavity of the lateral outline about two-thirds down marks superfically the division into the *body* above, and the *cervix* or *neck* below; but the interior shows more clearly the distinction. The cavity of the body is triangular, with the anterior and posterior walls in contact, and with all

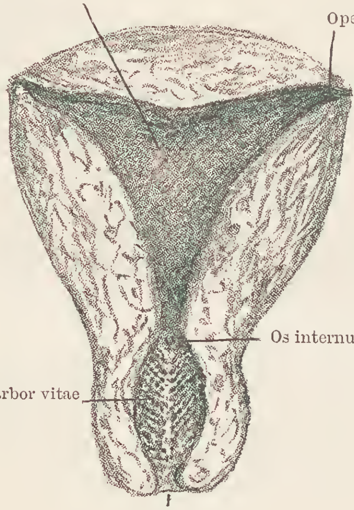


FIG. 614.—UTERUS, in vertical transverse section.

three margins curving inwards, and has a perfectly smooth surface. Its upper angles taper to the Fallopian tubes, and represent the parts which are prolonged into cornua in many animals; and its lower angle is separated by a constriction termed *os uteri internum*, from the cavity of the cervix. The cavity of the cervix is limited below by another constriction, the *os externum*, and has its walls circularly compressed. Its surface is marked by two longitudinal lines, one in front and one behind, from each of which

[1] The ovaries were recognised as homologous with testes by Galen, and continued to be called *testes muliebres* till the time of De Graaf. Fallopius mentioned in the testes muliebres both clear vesicles and yellow bodies, but it was left for De Graaf to give a description of both, and to demonstrate that mammals had ovaries like oviparous animals, and that the Fallopian tubes received ova from them; while it was not until 1827 that the true mammaliam ovum was discovered by von Baer.

a number of rugae extend upwards and outwards, giving an appearance known as *arbor vitae* or *palmae plicatae.* The os externum is in the virgin uterus a transverse orifice, about $\frac{1}{12}$th inch in extent; and the vaginal part of the cervix, in front and behind it, takes the form of two lips, of which the anterior descends further than the posterior, although the vagina is prolonged further behind the posterior lip than in front of the anterior lip; hence the os externum (called from the inequality of the lips *os tincae*) looks to the posterior wall of the vagina.

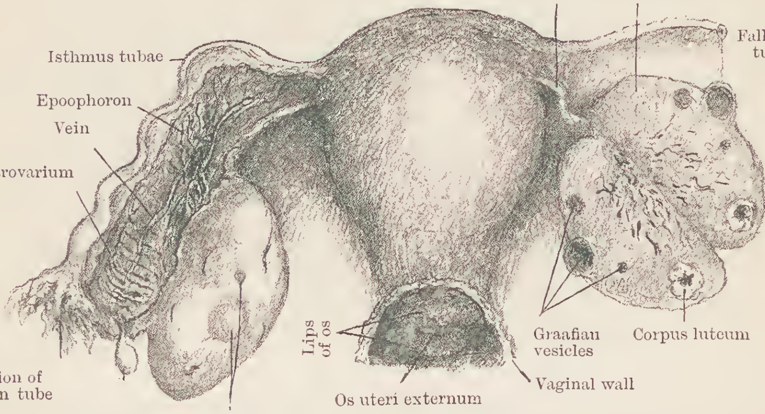


FIG. 615.—UTERUS, OVARIES AND FALLOPIAN TUBES from behind.

The whole posterior surface of the uterus above the vagina, the upper end or *fundus*, and the anterior surface of the body are covered with peritoneum, while the fore part of the cervix, down to the vaginal attachment, is in contact with the bladder, and, at the sides, the uterine vessels and nerves lie between the folds of peritoneum constituting the broad ligament of the uterus. In the upper edge of the broad ligament the Fallopian tube is placed, and in a projecting anterior fold of the broad ligament a strong band of fibres, the *round ligament of the uterus*, extends outwards from immediately below and in front of the origin of the Fallopian tube to the internal abdominal ring. Having reached that ring the round ligament loses its peritoneal investment, and traverses the inguinal canal, like the spermatic cord in the male, and emerges to be lost in the connective tissue of the labium majus.

Structure. The muscular wall is resolvable into three layers, very closely connected one with another and difficult to follow. The superficial fibres are longitudinal in front and behind, the majority arching over the fundus, but those situated more to the sides curving outwards as they ascend, and extending into the round ligaments of the uterus and on to the walls of the Fallopian tubes. Much the thickest layer is the next, and has the fibres very intricately arranged winding among numerous vessels in the body, but becoming circular in the cervix. The innermost layer

has its fasciculi interspersed with areolar tissue and tubular glands, and is arranged longitudinally in the cervix, obliquely higher up, and circularly toward the mouths of the Fallopian tubes. But even these distinctions into layers are vague, and there seems no advantage to be gained by calling the inner fibres *muscularis mucosae*, as has been proposed (Williams), for that could only indicate a layer belonging to the mucous membrane, and separated from the others by a submucous layer of loose tissue, whereas the most marked peculiarity of the mucous membrane of the uterus is that it is not separated from the subjacent textures by any such layer. The epithelium lining the uterus is simple columnar ciliated. The surface outside the os externum has stratified scaly epithelium continuous with that of the vagina. This is continued at first into stratified columnar epithelium on the prominent ridges of the cervix, while already the recesses between have ciliated columnar epithelium. Scattered through the mucous membrane of the body are elongated, straight or somewhat winding tubular follicles (*glandulae utriculares*), lined, unlike secreting glands generally, with ciliated columnar epithelium. And these extend also down into the upper part of the cervix, but in the lower part are exchanged for wider follicles with cubical epithelium secreting mucus. Clear vesicles (*ovuli Nabothi*) also occur, embedded in the mucous membrane of the cervix, probably resulting from closure of some of the mucous follicles (Toldt). In menstruation there is at first a general swelling and softening of the whole mucous membrane, increased vascularity, also enlargement of the epithelial cells, and afterwards extravasation, formation of oil globules both within and around the epithelial cells, and abundance of lymphoid corpuscles or leucocytes.

Vessels and nerves. The uterus is principally supplied with blood by the right and left uterine arteries, given off from the anterior divisions of the internal iliac arteries. These reach it opposite the cervix. Each gives off a vaginal branch downwards, and is directed upwards on the side, giving off undulating branches to the anterior and posterior walls, and anastomosing above with the ovarian artery along by the Fallopian tube. The uterine and ovarian veins anastomose much more freely than the corresponding arteries. The lymphatics are very abundant, and are deep and superficial. The nerves are derived from the inferior hypogastric plexus, which are joined by branches from the third and fourth sacral nerves.

Bicornute uterus is an abnormality arising from imperfect development. The uterus may divide into two cornua or be completely double, and the vagina may partake either in whole or in part in the duplicity. *One-horned uterus* results from suppression of the part connected with one Fallopian tube.

In pregnancy the menstrual thickening of the mucous membrane, instead of terminating with relief of the swollen capillaries, associated with a certain degree of fatty degeneration of texture, goes on further to the formation of the decidua (p. 103). The rapid increase of the uterus is accompanied with ascent into the abdomen, and the cervix undergoes remarkable changes,

the lower part secreting a tenacious substance, while the upper part would appear to alter its relations and enter into the formation of the enlarged body.

The Fallopian tubes are the ducts by which the ova, escaped from the ovaries, reach the uterus. They are between three and four inches long, and open by one extremity (*ostium uterinum*) into the uterus, and by the other (*ostium abdominale*) into the peritoneal cavity. They spring abruptly from the uterus, and are continuous with the superior and lateral angles of its cavity. For about an inch from its uterine extremity the Fallopian tube is so narrow as only to admit a bristle, and this part is known as the *isthmus.* Beyond it the tube dilates in the rest of its length to about an eighth of an inch in diameter, and is again slightly narrower close to the peritoneal orifice, and the dilated part is often alluded to as the *ampulla.* The peritoneal orifice is expanded like the corolla of a flower, and the free margin of its expansion is prolonged into fringe-like processes, the *fimbriae,* one of which is attached by peritoneum so as to approach close to the outer end of the ovary, while to another there is often appended a minute cyst, probably vestigial, like the hydatids of Morgagni in the male.

The mucous membrane is lined with simple ciliated columnar epithelium up to the edge of the fimbriated extremity. It is thrown into longitudinal rugae, which are simple in the isthmus, but in the ampulla bear secondary rugae, and communicate one with another and exhibit blind recesses. Beneath the mucous membrane there is a submucous layer of connective tissue containing some longitudinal muscular fibres. The main thickness of the muscular coat consists of circular fibres, but there are some longitudinal fibres external to them.

The Fallopian tubes are supplied by the ovarian vessels and nerves.

The parovarium (*epoophoron* or *organ of Rosenmüller*) is a vestigial structure, the epididymis and coni vasculosi of the male. It is without apparent function, and is seen to advantage on holding up against the light the fold of peritoneum between Fallopian tube and ovary. It is always present, but is most distinct in young subjects. It consists of a thread-like tube running parallel to the outer part of the Fallopian tube, with several others (not, however, tubules of the Wolffian body) coming off from it and running towards the ovary. No opening has been found into those tubes. They contain ciliated columnar epithelium. Other vestigial remains placed nearer to the uterine end of the Fallopian tube have been named *paroophoron.*

II. The External Organs of the Female.

Under this head may be included the superficial sexual parts, together with those near the surface, or opening in its neighbourhood.

The superficial parts, *pubes* or *pudendum,* consist of the vulva, bounding the genito-urinary orifice, and the mons veneris. The *mons veneris* is the prominence of thickened adipose and areolar tissue on the front of the pubes, covered with hair, the abdominal margin of which differs from the

corresponding part in the male in forming one crescentic curve from side to side, instead of two which meet in the middle line. The *vulva* is limited externally by thickened margins, labia majora, continued back from the mons veneris; and internal to them presents two smaller folds, the nymphae, meeting together in front at the praeputium clitoridis. The *labia majora* are rounded and filled out with adipose tissue from infancy till after the prime of life, and are liable to shrivel at a later period. Into them may be traced from above the deep layer of the superficial fascia of the abdomen and the round ligament of the uterus, which both become lost in the web supporting the adipose tissue, which is distinct from the adipose tissue of the thigh and hinder part of the perineum, and still more firmly separated from the nymphae. The points where the inner margins of the labia majora meet in front and behind are called the *anterior* and *posterior commissures*, and the posterior commissure has in the uninjured condition a bridle-like margin or fraenulum often called the *fourchette*.

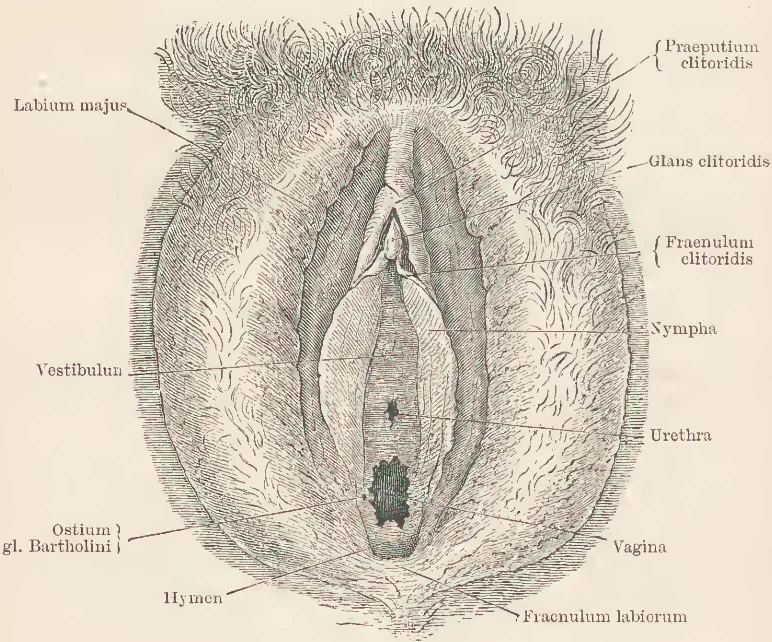


Fig. 616.—Female Genitalia. (Pansch.)

The nymphae, or *labia minora*, are a pair of narrow tegumental folds internal to the labia majora. They meet together in front in connection with an erectile prominence, the *glans clitoridis*, hid in a smooth depression within the anterior commissure. They bifurcate on approaching the glans, the upper division joining with its fellow above that structure to form the *praeputium clitoridis*, and the lower division meeting its fellow on the under surface of the glans to form the *fraenum clitoridis*. The nymphae

are of a firm fibrous texture, but contain a number of minute arteries which may give serious trouble when divided during life. Though hairless, they have numerous branched sebaceous glands opening on both their inner and outer surface. Occasionally the nymphae are considerably longer than usual; and in Hottentot women they form an "apron" which may descend for several inches.

The vestibule is the space bounded superficially by the nymphae and deeply by the position of the hymen. Anteriorly it presents a smooth depression bounded by the glans clitoridis in front and by the rough surface within the vagina behind. It is covered with stratified squamous epithelium. In the deepest part of this depression just in front of the vaginal orifice is the *meatus urinarius* which, from its position, can always be quite easily detected with the finger, without the aid of vision, as a pit. Acinated mucous glands open on the surface of the vestibule.

The hymen is a membrane which, in the virgin, is stretched more or less completely across the entrance to the vagina. Its typical and proper form is best understood by examining it in the foetal condition. It is developed as a funnel-like fold of mucous membrane, prolonging the vagina downwards behind, but absent in front so as to place the opening of the vagina immediately behind the meatus urinarius. As growth proceeds, the opening does not develop at the rate of the parts around, and the hymen comes thus to form a septum across the entrance into the vagina. While the normal position of the opening is undoubtedly in front, cases occur both of imperforate hymen and, more frequently, of irregular apertures, very probably the result of a prior imperforate condition. Little papillary prominences left at the line of attachment of the hymen after its destruction are called *carunculae myrtiformes.*

The female urethra, opening into the vestibule, as already described, is an inch and a half long, wider than in the male, and lies parallel and close to the vaginal wall, so that when the meatus has been found with the tip of the finger, an instrument slips in easily if the finger be slid slightly into the vagina and the instrument pointed in the same direction. The muscular wall is strong, its innermost fibres longitudinal, the others circular, the outermost layers containing striped fibres. The mucous membrane is thrown into longitudinal folds which in the lower half are unobliterable, and have between them little crypts looking downwards; and some of the lowest of these are prolonged upwards and branched (as figured first by De Graaf), and are lined with cylindrical epithelium. The urethra itself is lined in its upper part with epithelium like that of the bladder, and its lower half like that of the vestibule. In its upper half tubular mucous glands are found.

The clitoris consists of two corpora cavernosa, like those of the male, but smaller, surmounted by a rudimentary glans. The corpora cavernosa spring each from a crus attached to the arch of the pubis and covered by an erector clitoridis muscle. They join to form a body an inch and a

half long with a more or less complete septum between. The body is hid in adipose tissue and loosely attached by a suspensory ligament to the lower part of the symphysis pubis, but it is surmounted by a glans distinct from the corpora cavernosa.

The bulbi vestibuli are two erectile masses of convoluted veins placed one on each side of the vestibule at the attached border of the nymphae and internal to the sphincter vaginae muscle. They receive blood from the nymphae and pass it forwards into a number of larger veins between

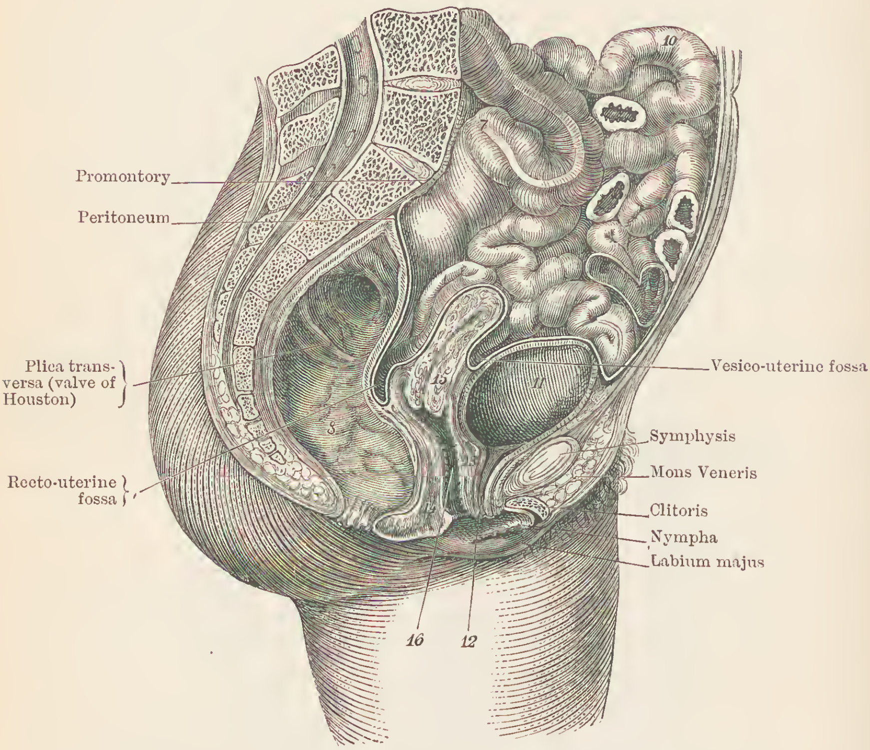


FIG. 617.—MESIAL SECTION OF FEMALE PELVIS. 7, Sigmoid flexure; 8, rectum; 10, small intestine; 11, bladder; 12, urethra; 13, septum urethro-vaginale; 14, septum recto-vaginale; 15, uterus; 16, vagina. (Luschka.)

it and the glans clitoridis, whence it is conveyed upwards into the vaginal plexus. The bulbi vestibuli correspond with the corpus spongiosum of the male, and the sphincter vaginae with the acceleratores urinae, while the nymphae correspond with the spongy part of the urethra and the integument on the under surface of the penis.

The glands of Bartholin, or of *Duverney*, sometimes also called *Cowper's glands* because corresponding with Cowper's glands in the male, are two small acinated glands about the size and shape of field-beans. They lie close to the posterior commissure, partly under cover of the deep transverse

perineal muscles, and pour their secretion each into a long duct which opens into the vestibule well forward.

The vagina, the passage extending from the vestibule to the uterus, has in front of it the urethra, with which it is closely connected, and also the bladder, while the rectum is in contact with it behind, excepting for a little distance above, where the pouch of Douglas intervenes. At the sides it is supported by the recto-vesical fascia, by which and the levator ani it is separated from the ischio-rectal fossa. Being curved, and also prolonged further up on the posterior than on the anterior lip of the uterus, it has a greater length of posterior than of anterior wall.

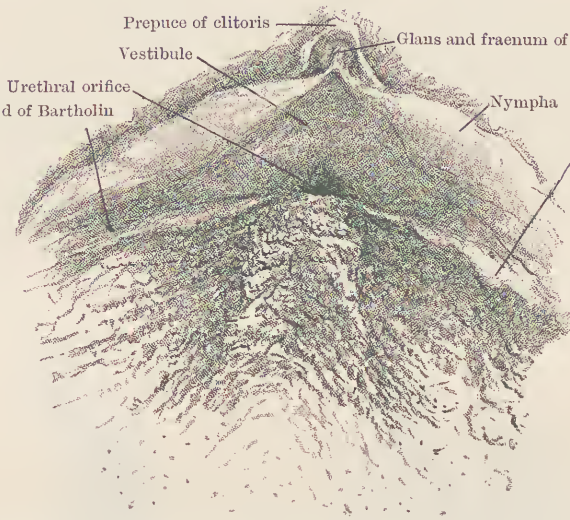


Fig. 618.—External Organs of Female, with Lower Part of Vagina, laid open from behind.

The mucous membrane is continuous below with the vestibule or hymen as the case may be, and is reflected above on the lips of the uterus. It has stratified squamous epithelium, and is furnished with papillae more abundant in the lower part, and with mucous glands more abundant in the upper part. It is thrown to a variable extent upwards into rough transverse rugae, which are specially prominent at the lower end, and gathered together in *anterior* and *posterior columns*, from which they arch upwards as they become less prominent on the sides. Both the anterior and posterior columns have a tendency to duplicity, but the mesial part of the anterior column is projected by the thick muscular wall of the urethra. The anterior and posterior columns lie in contact one with the other, while the lateral parts of the wall are pressed against them so as to give a transverse section the form of the letter H. The muscular wall presents longitudinal and circular fibres not separable into distinct layers, and the lower and anterior part is not distinctly separable from the fibres surrounding the urethra. In the mucous

membrane there is free supply of vessels to the papillae, and in the muscular substance there is an abundance of winding and anastomosing veins which is sometimes referred to as erectile tissue, while a plexus of larger veins is particularly rich round the lower part of the vagina and the urethra. In the fibrous tissue round the muscular wall numerous small ganglia are said to exist.

DEVELOPMENT OF THE REPRODUCTIVE ORGANS.

As already stated (p. 97), a tract of *germinal epithelium*, different from the cells which bound the rest of the abdominal cavity, appears in the embryo on the surface of the Wolffian body, and it is from this that, according to the sex, the essential reproductive elements of the testicle or of the ovary are developed. In both sexes a white body covered with a thickening of this epithelium becomes apparent on the inner side of the crimson-coloured Wolffian body, mid-way between its extremities, before it has begun to dwindle or change its position, but the ovary is from the first of a distinctly longer shape than the testicle. Indeed, this difference of shape is, in man and in other mammals with short or pendulous penis, the earliest indication by which the sex can be determined, though in pigs and ruminants the production of the penis toward the umbilicus affords a more obvious distinction.

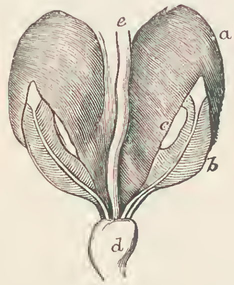


FIG. 619.—OVARIES AND WOLFFIAN BODIES OF EMBRYO PIG, $\frac{2}{1}$. *a*, Kidney; *b*, Wolffian body, and on its surface the Müllerian duct; *c*, ovary; *d*, urinary bladder turned down; *e*, rectum.

FIG. 620.—ORGANS ON RIGHT SIDE OF EMBRYO RAM. *a*, Kidney; *b*, suprarenal capsule; *c*, testis; *d*, Wolffian body; *f*, vas deferens; *g*, coni vasculosi; between *f* and *g*, epididymis; *i*, ureter.

The ovary has been more fully worked out in its development than the testicle. The ova destined to be discharged periodically after sexual activity has been arrived at are cells of the germinal epithelium. From an early period of foetal life certain of these cells become round, and assume all the characters of minute ova; they are carried in, partly at least, by the growth of the deep-seated connective and vascular tissue; other smaller epithelial cells follow them, and thus elongated masses are embedded in tubules of

stroma. At intervals other cells in these masses assume the characters of ova, and the stroma separates each ovum with its surrounding cells from the others, so as to produce separate Graafian follicles arranged at first in *chains* or *egg-bands* (Fig. 612).

The testicle seems on the whole to be well made out to have its seminal elements derived like those of the ovary by intrusion of epithelial elements, arranged in processes which become elongated as the connective and vascular tissue grows up round about them.

Ducts. The Müllerian duct can be easily seen with the naked eye, forming on the outer border of the Wolffian body at the time of its maximum development a prominent white column; and in connection with the upper end of this column there is soon afterwards seen in both sexes a white *conical mass* (Cleland, 1856) containing tubules, and in greater part distinct from the Müllerian duct, which duct turns inwards in front of the base of the conical mass to terminate on the inner border (Banks, 1864).

In the female the Müllerian duct is developed in so far as it is in contact with the Wolffian body into the Fallopian tube, and the lower end of the Wolffian body marks the point where uterus and Fallopian tube meet. To this point a cord descends from the lower end of the ovary, and becomes developed into round ligament of ovary, while continuous with it another fold extends to the inguinal canal, and becomes round ligament of uterus. But the two ligaments are not long continuous in direction, as the Wolffian body and the ovary are rotated outwards, and the deep end of the inguinal canal also retreats from the mesial plane. In later development the peritoneum descends into the inguinal canal for a short distance on the round ligament of the uterus as a pouch, the *canal of Nuck*. The Müllerian duct opens at first independently of its neighbour into the uro-genital sinus; but while in monotremata and non-mammalian vertebrates it remains distinct from its fellow, in all placental mammals the ducts of opposite sides become fused into one tube a little distance from their outlets to form the fundus uteri, and the fusion is afterwards extended as far as the sinus so as to make a single vagina. It is failure in this fusion which produces various anomalies met with in the human subject, such as bicornute uterus and duplicity of vagina.[1]

In the male the Müllerian ducts are early arrested in development. The united part of the two ducts remains as the *sinus pocularis*; which (as first pointed out by Banks) represents both uterus and vagina, while the portion of the male urethra between the sinus and the bladder is homologous with the female urethra. The ununited portions of the Müllerian ducts persist in the male in many mammals as cornua of the sinus pocularis and two threads extending from them. The *vas deferens* is developed from that part of the Wolffian duct between the base of the

[1] Specimens in my museum demonstrate that, in marsupials, the ureters pass between the two vaginae to reach the bladder. In this respect the marsupial arrangement is not comparable with anomalous double vagina in the human subject.

Wolffian body and the sinus uro-genitalis. The *epididymis* is developed close behind the Müllerian duct, along the outer side of the Wolffian

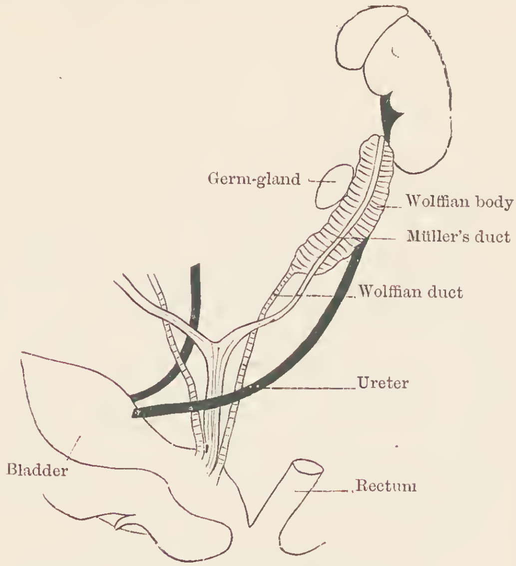


FIG. 621.—UNDIFFERENTIATED.

FIGS. 621, 622, 623.—DIAGRAMMATIC VIEW OF THE DEVELOPMENT OF THE SEXUAL ORGANS. (Pansch.)

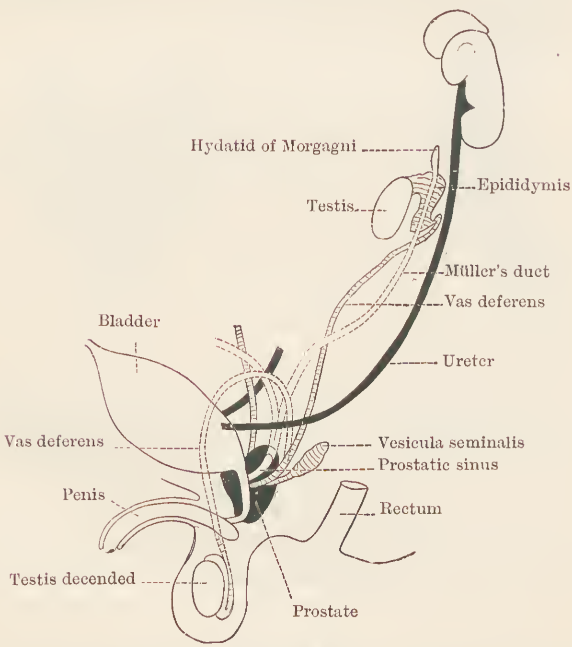


FIG. 622.—MALE.

body, and is held to be the altered Wolffian duct. But it is beyond doubt

that the *coni vasculosi* and commencement of the epididymis are developed in the conical mass surmounting the Wolffian body. The canals of this mass remain in the female as the parovarium (or epoophoron), while the portion of it which forms in the female the extremity of the Fallopian tube persists as the hydatid of Morgagni in the male. The proper substance of the Wolffian body leaves only small vestiges in either sex, viz., in the male, the organ of Giraldès, and in the female, the paroophoron.

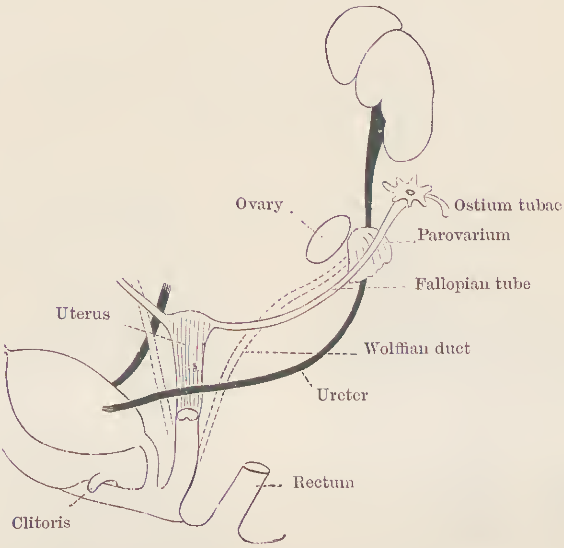


FIG. 623.—FEMALE.

Descent of the testicles. Unlike the ovary, the testicle retains the longitudinal position, while it gradually descends and carries with it the epididymis on the outer side and the vas deferens on the inner. It reaches the internal inguinal ring about the end of the sixth month of foetal life, and usually completes its descent about the beginning of the ninth month. A band homologous with the round ligament of the ovary passes from the lower end of the testicle to the lower end of the Wolffian body. It joins the testicle to the point where the epididymis becomes vas deferens, and is the upper portion of the structure named by Hunter *gubernaculum testis.* Continuous with it, a larger band descends to the inguinal canal, and thence afterwards to the scrotum, constituting the lower, larger and more generally recognised portion of the gubernaculum, homologous with the round ligament of the uterus. The upper portion very early disappears by the shrinking of the Wolffian body and approach of the testicle to the globus minor of the epididymis, while the lower portion becomes more fully developed and extends down into the scrotum. The peritoneal sac is prolonged downwards as *processus vaginalis* prior to the testicle leaving the abdomen, and reaches the bottom of the

scrotum before the testicle has quite entered it. The gubernaculum presents a band extending from the fascia transversalis to the bottom of the scrotum, with fibres passing upwards and downwards on it from the different depths of the abdominal wall, and a projection into the pouch of the tunica vaginalis, inclosed in a fold called *plica gubernatrix*; but the contents of the plica do not extend beyond the pouch of the processus vaginalis, and the cremaster muscle is from the first directed downwards. The descent of the testicle sometimes fails to be completed on one or both sides, in which case the patient is called a *monorchid* or *cryptorchid*. This failure of descent may or may not be accompanied with arrest in size. Sometimes descent proceeds again in the young adult and gives trouble in the inguinal canal.

FIG. 624.—LEFT TESTIS AND GUBERNACULUM IN FOETUS OF FIFTH MONTH. *a*, Testis; *b*, vas deferens; *c*, processus vaginalis slit open; *d*, plica gubernatrix; *e*, the cavity described by Weber as a shut sac; *ff*, fibres inserted inferiorly in a bundle into the scrotum, and superiorly into the abdominal wall; *g*, fibres to the processus vaginalis; *h*, internal oblique muscle; *i*, aponeurosis of the external oblique muscle; *k*, integument reflected down.

FIG. 625.—DISSECTION OF A MAMMA IN ACTIVE CONDITION. The nipple is left undissected. On it are seen the openings of the galactophorous ducts, and, beyond it, their ampullae embedded in connective tissue, while the lobules are round about.

External organs. Before the fifth week there is a cloaca common to the rectum and genito-urinary organs. By the eighth week the anus is completely separated as a rounded orifice from the genito-urinary opening, which forms in both sexes a mesial slit, surmounted by an organ which may be developed either into clitoris or penis. Thereafter, the margins of this aperture come together in the male to form the raphe of the scrotum and the wall of the spongy part of the urethra, while in the female they remain separate as the nymphae and labia majora. The corpora cavernosa appear separately and afterwards unite.

THE MAMMARY GLANDS.

The mammae, like the other organs connected with reproduction, are represented in both sexes. They are fully developed in the female only. Their representatives in the male are in no way altered or disguised, but simply arrested in development. Both in the virgin and in the male the nipples are on a level with the lower end of the body of the sternum; and in the virgin they form with the depression between the clavicles an equilateral triangle.

The glandular substance of the mamma is arranged in a circular disc around the nipple. It lies in the subcutaneous adipose tissue, which penetrates more or less between its lobules. The integument on its surface is easily removed, as is also a firm layer of superficial fascia beneath the deep surface of the gland, while between its lobules the meshwork of connective tissue is abundant and tough, forming as it were shut locules. Hence it happens that superficial abscesses rise up easily and give little

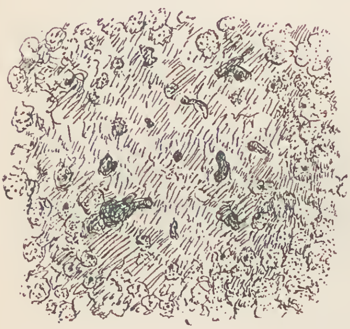


FIG. 626.—SECTION THROUGH CENTRE OF MAMMA, parallel to base of nipple. The ducts are seen embedded in tough connective tissue; while lobules are scattered round about. Natural size.

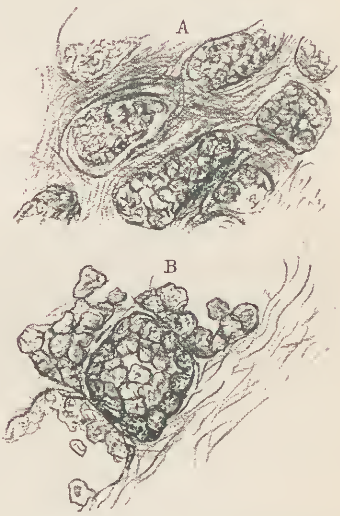


FIG. 627.—SECTIONS OF HUMAN MAMMA READY FOR LACTATION. *A*, lobules in fibrous stroma, $\frac{20}{1}$; *B*, acini and secreting corpuscles, $\frac{200}{1}$.

trouble, and a single abscess may enlarge to a considerable size on the deep surface before being detected; but the more frequently occurring abscesses in the substance of the gland are multiple and require to be separately opened. Both the circumference and the deep surface of the mamma are thrown into a number of large lobes consisting of smaller lobules or groups of ultimate acini, and these are lined with an epithelium of small cells which when active expand laterally, and subsequently in depth also, while both they and the interior of the acinus are filled with milk characterized by its butericeous globules of different sizes.

The galactopherous ducts are from twelve to twenty, and open by minute orifices at the extremity of the nipple. Traced backwards, each gradually enlarges, forming an *ampulla* or *sinus* widest towards its deep end, where it is capable of being swollen to quarter of an inch or more in diameter, and extending an inch or more from the base of the nipple. Each ampulla originates in the union of two ducts, themselves formed by the union of others in pairs. In sections of specimens prepared with acid (*e.g.* sulphuric) the closely set and larger masses of secreting lobes are seen arranged at the circumference, while in the deeper parts the sections of lobules are small and separated by copious connective tissue, and in the centre the connective tissue is collected in a large mass between and around the ampullae. The walls of the ducts are highly elastic and lined with columnar epithelium.

The nipple (*mammilla*) and the rosy ring around it (*areola*) have adherent to the integument a well-marked layer of circularly arranged unstriped muscle which no doubt in contracting obstructs the cutaneous veins, and in conjunction with a considerable vascularity of these parts causes turgidity, approaching in the nipple to erection. The interior of the nipple is destitute of fat and contains the narrowing ducts emerging from the ampullae. The areola often presents a tuberculated appearance dependent on large sebaceous glands (glands of Montgomery).

In the male the mammary gland, though rudimentary, is complete in its parts, its feeble development being merely the permanence of the condition in children both male and female.

Vessels and nerves. The arteries are derived in an inconstant manner from the long thoracic or external mammary and some of the anterior intercostal branches of the internal mammary. The nerves are from anterior and lateral cutaneous branches of intercostal nerves. The lymphatics pass principally to the axillary glands, but some of them join the internal mammary plexus.

Supernumerary mammae occasionally occur both on the chest and on other parts. They are mostly small and liable to be mistaken for moles, but one or more may reach a considerable size.

APPENDIX.

ON THE UTILIZATION OF RÖNTGEN RAYS.

Since this book was taken in hand, and even since the completion of the bulk of the manuscript, there has come before the world a revelation of the possibility of seeing structures in the interior of the living body. The part to be played in this respect by the Röntgen rays is as yet only beginning to be seen, but sufficient progress has been already accomplished to make it rash for any one to limit the amount of anatomical detail which may ultimately be displayed by their aid. Meanwhile it is fitting in this place to acknowledge the existence of an agent which may be utilized not merely in Surgery and Pathology, but in studying with accuracy the relations of healthy organs. I content myself with taking the joints at the wrist for illustration.

Through the kindness of Dr. Macintyre of this city, whose successful experiments in this new branch of inquiry have already done much and are full of promise for the future, I am enabled to exhibit the shadows cast by the bones of this region when the hand is in a straight line with the pronated forearm, when it is bent over to the ulnar side as far as it will go, and when pressure is made on it in over-extension. Every anatomical student has already had the opportunity of seeing in the views sold in the shops that the cuneiform is not in the relation to the ulna which has generally been supposed. It is to be clearly understood at the outset, that cartilage presents no apparent hindrance to the passage of the rays, and that therefore articular surfaces, even when pressed together, exhibit a space between them. But after making allowance for the thickness of the articular cartilages and of the radio-ulnar triangular fibroplate, the gap between the ulna and cuneiform bone when the hand is stretched out is exceedingly remarkable. Nor is this all. The semilunar is to a considerable extent underneath the fibroplate, and its upper surface only half the vertical distance below the lower surface of the ulna that the nearest point of the cuneiform is, while the upper articular surface of the cuneiform looks more to the side than upwards. One has to recall to mind that the triangular fibroplate is not an articular cartilage, and to acknowledge that we have gone too far if we have looked on its contact

with the cuneiform bone as the play of two articular surfaces. One sees also that where articular surfaces are opposed, as the upper surfaces of the scaphoid and semilunar are to the radius, each surface presses in all positions

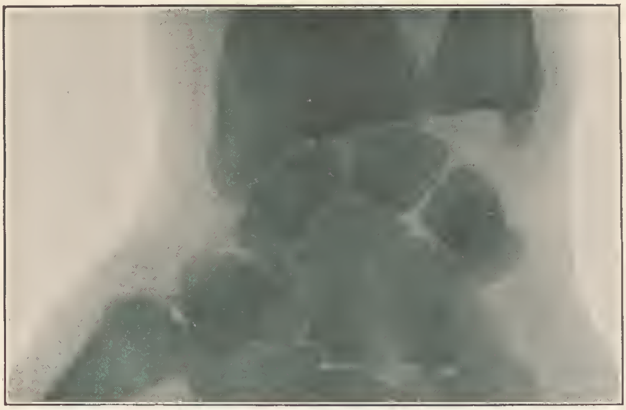


FIG. 628.—RÖNTGEN-RAY-SHADOW OF WRIST OF HAND, stretched in a line with the forearm.

only on the district specially set aside for it, and never on that set aside for another. When the hand is in a line with the forearm, the inner part of the scaphoid is indeed below the semilunar facet of the radius, but it

FIG. 629.—The same, with the stretched hand bent over the ulna.

is not in contact with it; and when the hand is inclined to the ulnar side, the semilunar bone is to a considerable extent beneath the scaphoid surface of the radius, but is very far from being in contact with it. In both lateral flexion and over-extension of the hand there is seen to be lateral movement

of the lower range of carpal bones on the upper range, for in both these positions the unciform is approached to the semilunar, while in the straight position of the hand it is quite separated from it. That this lateral movement is accompanied by movement in which the scaphoid and cuneiform are thrown back at the extremities removed from the semilunar is shown by the apparent elongation of scaphoid and cuneiform. This is in keeping with the description of movements given at p. 161; also the gaps there

Fig. 630.--The same, with the hand completely over-extended.

pointed out as existing in different positions between trapezium and first metacarpal are to a certain extent illustrated. Another point may be noted. The hand employed happened to be that of a man over sixty, and the shadows exhibit the lines of union of the shafts and epiphyses of the radius and ulna, a thing which might be seen over and over again in macerated bones without the age of the bones being known. This reminds us that much accurate information can now be got on the subject of the condition of epiphyses at different ages.

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